Rockwell International
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METHANE HEAT TRANSFER INVESTIGATION
8TH BI-MONTHLY TECHNICAL PROGRESS NARRATIVE
PERIOD OF PERFORMANCE: 14 APRIL - 14 JUNE 1984

CONTRACT NAS8-34977

Prepared for:
NASA/MSFC
Huntsville, Alabama 35812

14 JUNE 1984

Prepared by:

Ron Cook

Ronald T. Cook
Project Engineer

Approved by:

F. M. Kirby

F. M. Kirby
Program Manager
Advanced Booster Propulsion Systems

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ROCKETDYNE DIVISION, ROCKWELL INTERNATIONAL CORPORATION
6633 Canoga Avenue; Canoga Park, California 91304

FOREWORD

This is a 12-month program being conducted for NASA-MSFC. The NASA-MSFC Program Monitor is Dale Blount. The major efforts of this program are being conducted by the Rocketdyne Engineering Aerothermal, and Materials Departments. Testing is being conducted at the Rockwell North American Aviation Operations (NAAO) Aerothermal Laboratory. The responsible Engineers in these areas are:

Ron Morinishi	Heat Transfer, Testing, Data Analysis
Dennis Lim	Task I Thrust Chamber Thermal Analysis
Frank Wimmer	Materials & Processes
Bob Scherer	Test (NAAO)

The Project Engineer is Ron Cook, Advanced Programs, and the Program Manager is Frank Kirby.

INTRODUCTION

This program is a 12-month experimental investigation to determine the coking thresholds and cooling capability (convective correlations) of methane. Economical exploitation of space in the future will require reusable, high-performance, liquid rocket booster engines. The high propellant bulk density and relatively high-performance LOX/hydrocarbon liquid engines look extremely attractive. LOX/methane is of particular interest because it has a higher chamber pressure cooling limit, higher specific impulse, higher coolant coking temperature, cleaner exhaust products, and lower potential for carbon deposition at low mixture ratio preburner operation than other hydrocarbon fuels.

Future high chamber pressure LOX/hydrocarbon booster engines will require copper-base alloy main combustion chamber coolant channels similar to the SSME to provide adequate cooling and reusable engine life. Therefore, it is of vital importance to evaluate the heat transfer characteristics and coking thresholds for LNG (94% methane) cooling, with a copper-base alloy material adjacent to the fuel coolant.

High-pressure methane cooling and coking characteristics have recently been evaluated at Rocketdyne using stainless-steel heated tubes at methane bulk temperatures and coolant wall temperatures typical of advanced engine operation except at lower heat fluxes as limited by the tube material. As expected, there was no coking observed. However, coking evaluations need be conducted with a copper-base surface exposed to the methane coolant at higher heat fluxes approaching those of future high chamber pressure engines.

This program consists of five working tasks and a reporting task.

TASK 1: Test Matrix Definition consists of (1) design and analysis of a 600K LOX/CH_4 Main Combustion Chamber (MCC) at 3000 psia chamber pressure and (2) definition of the test matrix to cover the ranges of methane coolant conditions described in the MCC design analysis. The MCC design will utilize a high strength copper base channel configuration coolant liner, typical of the Space Shuttle Main Engine (SSME). The test matrix will provide for definition of coking thresholds and convective cooling heat transfer correlations.

TASK 2: Design and Procurement of Test Sections consist of designing electrically heated tubular test specimens and procuring associated test specimen hardware. The test specimens will utilize a bimetallic tube assembly to allow testing at a heat flux of 50 Btu/in^2-sec and 5000 psia CH_4 coolant pressure, which is typical of a 3000 psia chamber pressure MCC throat region coolant wall heat flux. The inner tube material will be copper to simulate any coking phenomena associated with the MCC liner material and surface conditions.

TASK 3: Preparation of Detail Test Plan consists of preparing a document that completely describes the test instrumentation, data acquisition, data correlation approach, heated tube specimen configuration control, and test procedures. The detailed test plan will include test section drawings, tube specimen operational maps, facility schematics, and data analysis processing procedures.

TASK 4: Heated Tube Testing will be conducted at the Rockwell North American Aviation Operations (NAAO) thermodynamics laboratory. Testing will be conducted to define the coking thresholds of methane at purities between 85% and 95% for LNG and near 100% pure methane. Coolant convective heat transfer characteristics will be evaluated at a purity between 94% and 100%.

TASK 5: Data Analysis and Correlation will be performed to define any coking thresholds and define convective cooling correlations for the complete range

of operating conditions applicable for a high chamber pressure MCC design. A number of convective heat transfer correlating formats will be satistically evaluated to obtain the best data-fit.

The program schedule, along with the work completed is shown in Table I.

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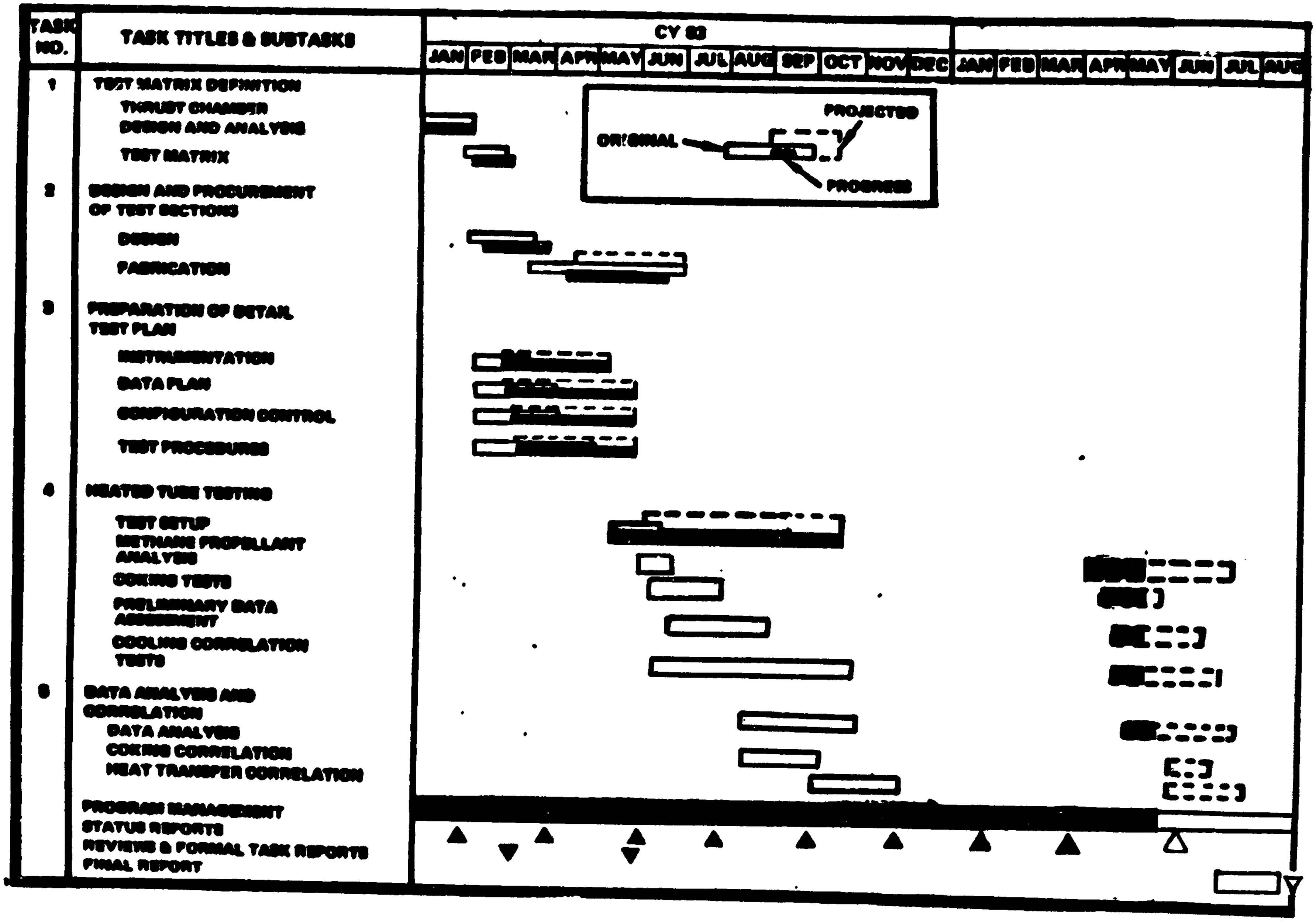
TABLE I (REVISED)

METHANE HEAT TRANSFER INVESTIGATION PROGRAM SCHEDULE



SUMMARY OF WORK ACCOMPLISHED

During this reporting period, the following work was accomplished:

1. The first 500 gallon shipment of liquid methane was received on 17 May 1984 as part of an 11,000 gallon load being carried from Trussville, Alabama to Orange County.

2. Tests were run using a seven inch heated tube. The test facility performed well; no test delays were encountered. The instrumentation measurement accuracy was verified by the data reduction results. The heat balance between the wattmeter electrical measurement and the fluid enthalpy rise agreed within ±5% for the majority of the test points.

3. Analysis of the methane test data points is underway. Preliminary results show that the data is consistent and falls within the expected form of the Nusselt correlation. All data reduction and graphical output is being performed on the IBM Personal Computer.

METHANE HEAT TRANSFER INVESTIGATION

DISCUSSION

TASK 4: HEATED TUBE TESTING

Testing of the first 500 gallons of methane has been completed. These tests accomplished the following goals of the first phase of the test plan: 1) verification of the bimetallic tube and test facility performance, 2) low heat flux range tests to provide heat transfer correlation data, and 3) heat transfer results which were within the predicted ±5% accuracy. The power reactors were driven up to 40 KWe (limit is 50 KWe) without the thermal runaway problem associated with the liquid nitrogen tests. All of these tests were performed on a single seven inch heated tube; no tube failures were encountered.

The methane chemical characteristics shown in Table 1 were provided by L. Hood Associates. Since the 500 gallons was delivered as part of a large shipment (approximately 10,000 gallons), it was assumed that the chemical make up was unchanged due to any boil-off during transit. However, a small sample of the methane was taken at the conclusion of the tests and will be analyzed.

The bimetallic tube temperature response to power input was well controlled, due to both the employment of fine tuning rheostats and the development of a test procedure which came from experience gained in the nitrogen tests. It was found that the desired tube temperature could be achieved more easily by first setting the desired power level (electrical current), then changing the fluid flow rate. Attempting to control the tube temperature by varying the power reactor inputs resulted in a "drifting" response. The general procedure for establishing a steady-state test point was to:

1. Start the fluid flow (about 2 gpm).
2. Turn on preheaters and activate power reactors.

3. Quickly ramp up the power, while maintaining a safe tube temperature by simultaneously increasing the flow rate.
4. Once power is set, then achieve desired tube temperature by varying flow rate.
5. Allow system ot reach steady-state for at least 25 seconds, then go to next test point.

This procedure required the coordination of two operators - one controlling the power reactors, and the other controlling the flow rate while monitoring the tube wall temperature.

The test was halted when over 25 gallons was flowed. This was indicated by a real-time integrator which is incorporated in the flowmeter counter. Note that although the run tank has a 33 gallon capacity, only about 25 gallons is usable due to the compressibility of the liquid. On a couple of occasions during the testing, the run tank was inadvertantly allowed to run dry; however, the automatic shutdown device (which monitors tube maximum temperature) acted quickly enough to prevent any tube damage. The device was set for a 1000°F limit.

There were no problems encountered in the instrumentation during the test period. The subsequent data analysis verified the accuracies of measurements. The wattmeter appeared to be performing up to its specified ±3% accuracy.

TASK 5: DATA ANALYSIS AND CORRELATION

The data analysis was performed on the IBM Personal Computer. A code called METHANE was written to simultaneously solve for the electrical heat generation and heat conduction balance in the bimetallic tube. The convective heat transfer coefficient is calculated at several axial positions along the tube. Fluid properties are accounted for by utilization of property correlations derived from the NBS tables. The METHANE code provides the pertinent dimensionless quantities such as Nusselt, Reynolds, Prandtl, and Stanton numbers. In addition, the temperature and viscosity property ratios (evaluated at bulk fluid and near wall conditions) are given at each axial location.

The results of the METHANE code were then transferred to a statistical subroutine called NUCKLE which provides a best-fit correlation. The results from both programs were then graphically presented using the commercially available LOTUS 1-2-3 package.

The incorporation of all phases of the data reduction process into the PC allowed for quick and convenient analyses. Many of the test points were evaluated at the test site immediately after the run, providing valuable feedback for the test engineer.

The range of test conditions achieved during this period is shown in Table 2. The maximum heat flux of 25.8 Btu/sec-in^2 was achieved during the final run where the power reactors were outputting nearly 40 KWe. The tube wall was still a conservative 667°F, so a higher flux is possible on the seven inch tube. Limited runs were made at the higher flux levels due to the conservative test plan. Because of the thermal runaway problem encountered in the nitrogen tests, the initial methane tests were made by slowly increasing the power level. However, no indications of runaway were found.

The reduced data is shown in the Appendix section. Out of the 27 steady-state test points, only six had unacceptable heat balances --meaning that the measured

electrical power input to the tube did not match the measured enthalpy rise of the fluid. In most cases, the heat balance difference was within ±5%, which was the expected experimental accuracy. In the statistical fit process, only those data points with balances within ±8% were deemed acceptable. The unacceptable heat balances were found to be the result of unsteady test conditions at the time chosen for the data point. There was no correlation between power level and heat balance error as is shown in Fig. 1. Therefore, by taking more care in allowing the system to reach steady-state, acceptable results are achievable.

Since the standard correlation for convective heat transfer in pipe flow is the Dittus-Boelter equation, preliminary assessment of the reduced data was made by plotting Nu vs (Re^0.8 Pr^0.4) as is shown in Fig. 2. It is evident that the data is consistent; the data points fall along a nearly constant slope. Deviations from a constant slope are expected due to the varying fluid properties, and the large bulk fluid to tube wall temperature difference. This deviation in slope is evident in Fig. 3, which shows that as the fluid to wall temperature ratio decreases, the slope decreases from the Dittus-Boelter value of 0.023.

The best fit correlation for this preliminary form is,

$$Nu = 0.0163\ Re^{0.8}\ Pr^{0.4}$$

A much better fit is found by adding the temperature ratio term to the Nusselt equation. This is shown in Fig. 4. The temperature ratio term accounts for the variation in fluid properties between the bulk fluid and near wall conditions. Important temperature related properties are viscosity, thermal conductivity, specific heat, and density. The preliminary best fit correlation for this form is,

$$Nu = 0.0215\ Re^{0.8}\ Pr^{0.4}\ (Tb/Tw)^{0.29}$$

Another form of the Nusselt equation separates the effect of the fluid viscosity from the temperature ratio term. Therefore, a viscosity ratio term is added, based on the bulk fluid and wall conditions. As shown in Fig. 5, there is not

an obvious increase in the data fit; however, a slight improvement may show up in the statistical fit. This has yet to be run.

An interesting comparison was made with similar methane tests run at Rocketdyne in 1979 by John Page. In the previous experiments, stainless tubes were electrically heated. The bimetallic tube was so designed to provide higher flux capabilities and better inner wall temperature calculation accuracy. The comparison is shown in Fig. 6. The previous data seems to give higher Nusselt numbers (hence, heat transfer coefficients) at the same Reynolds and Prandtl numbers (hence, flow conditions). The correlation that corresponds to this data is very close to the Dittus-Boelter equation, displaying a slope of 0.021.

A check was made to substantiate the fact that both data reduction calculations do indeed use the same methane properties (NBS). Also, a double check on the analytical solution to the bimetallic tube heat conduction equation was performed in order to verify the METHANE data reduction accuracy. This was done by comparison to a thermal model of the tube made on the Rocketdyne Thermal Analyzer Program (TAP). The results are shown in Fig. 7. It is evident that the analytical solution used in METHANE is indeed giving the correct tube wall temperatures. Therefore, at this time it is not known why the previous data is substantially different than the bimetallic tube test results. Further review of the data reduction procedure used by J. Page is underway.

Preparations are already underway for the next test series. A 3 inch tube has been installed in the test stand and a preliminary checkout is being performed. The next test series will be at higher heat flux and mass flux levels. The main focus of these tests will be to identify the conditions for incipient carbon coking. These tests will commence upon receipt of the next methane shipment, expected by the last week of June 1984.

WORK PLANNED

The following activities will be conducted during the next report period:

1. Preparations for the next series of tests will be complet[illegible] Th[illegible] tests will utilize a short 3 inch tube in order [illegible] high heat fluxes. Incipient carbon coking will be invest[illegible]ed.

2. The data analysis will be completed for the Nusselt correlation phase of the tes[illegible] plan. Also, a detailed evaluation of the previous methane tests (by J. Page in 1979) will be performed in order to make a positive comparison with the current test results.

3. Testing will commence upon the delivery of methane, expected by 30 June 1984.

Table 1. Methane chemical composition

COMPONENT	MOLE %
Oxygen	0.020
Nitrogen	0.290
Carbon Dioxide	0.000
Methane	92.470
Ethane	6.042
Propane	0.929
I-Butane	0.113
N-Butane	0.099
I-Pentane	0.000
N-Pentane	0.000
Hexanes	0.025

Excerpt from the Chromatographic analysis report prepared by Southern Natural Gas Co., Measurement Dept, Birmingham, Alabama on 3/16/84.

Table 2. Range of test conditions achieved in first test series.

Total Number of Tests	14			
Total Number of Data Points	27			
Nusselt Number	1067	to	3467	
Reynolds Number	8.2 E5	to	3.8 E6	
Heat Flux	1.6	to	25.8	Btu/s-in2
Mass Flux	23.9	to	68.8	lbm/s-in2
Inlet Fluid Temperature	-139	to	-36	F
Outlet Fluid Temperature	-118	to	23	F
Inlet Fluid Pressure	3914	to	4966	psia
Fluid Velocity	181	to	781	ft/s

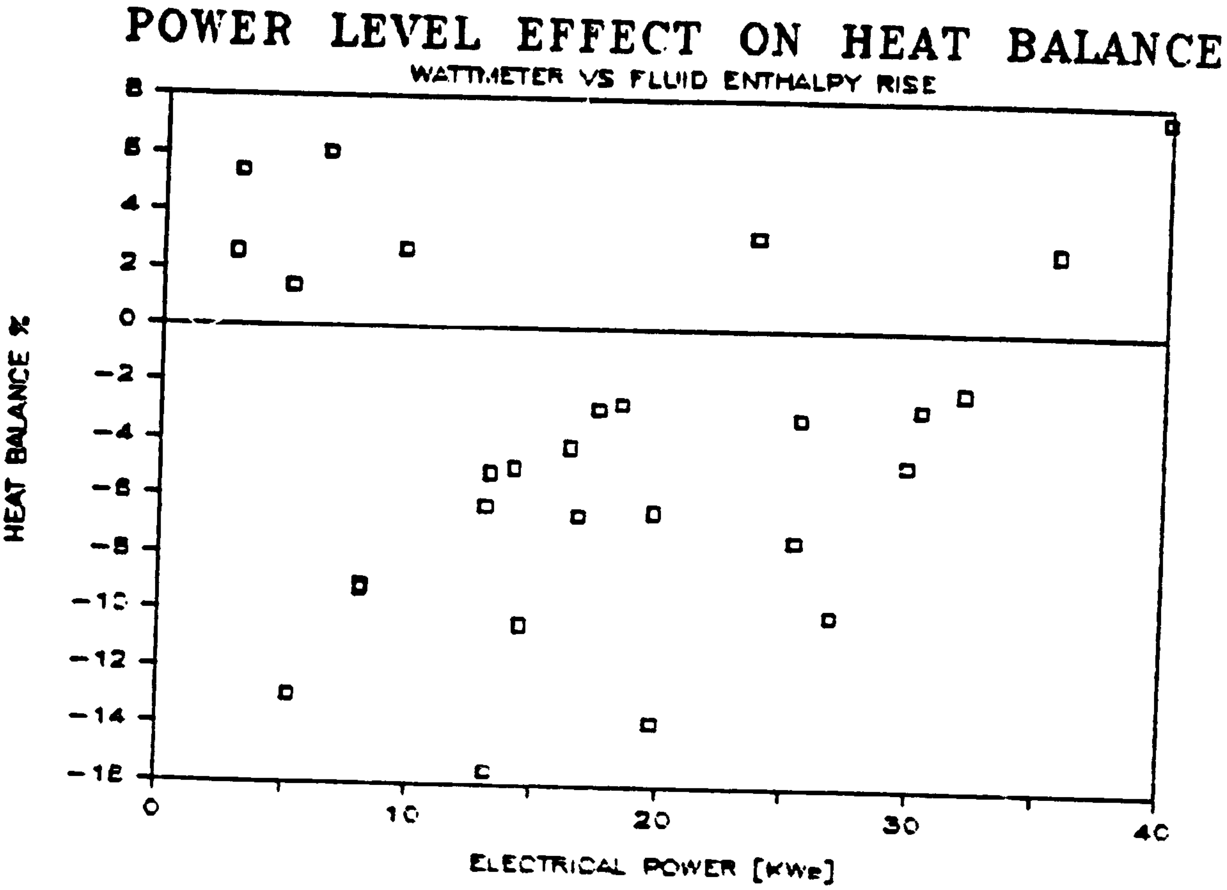


Figure 1. Power Level Effect on Heat Balance

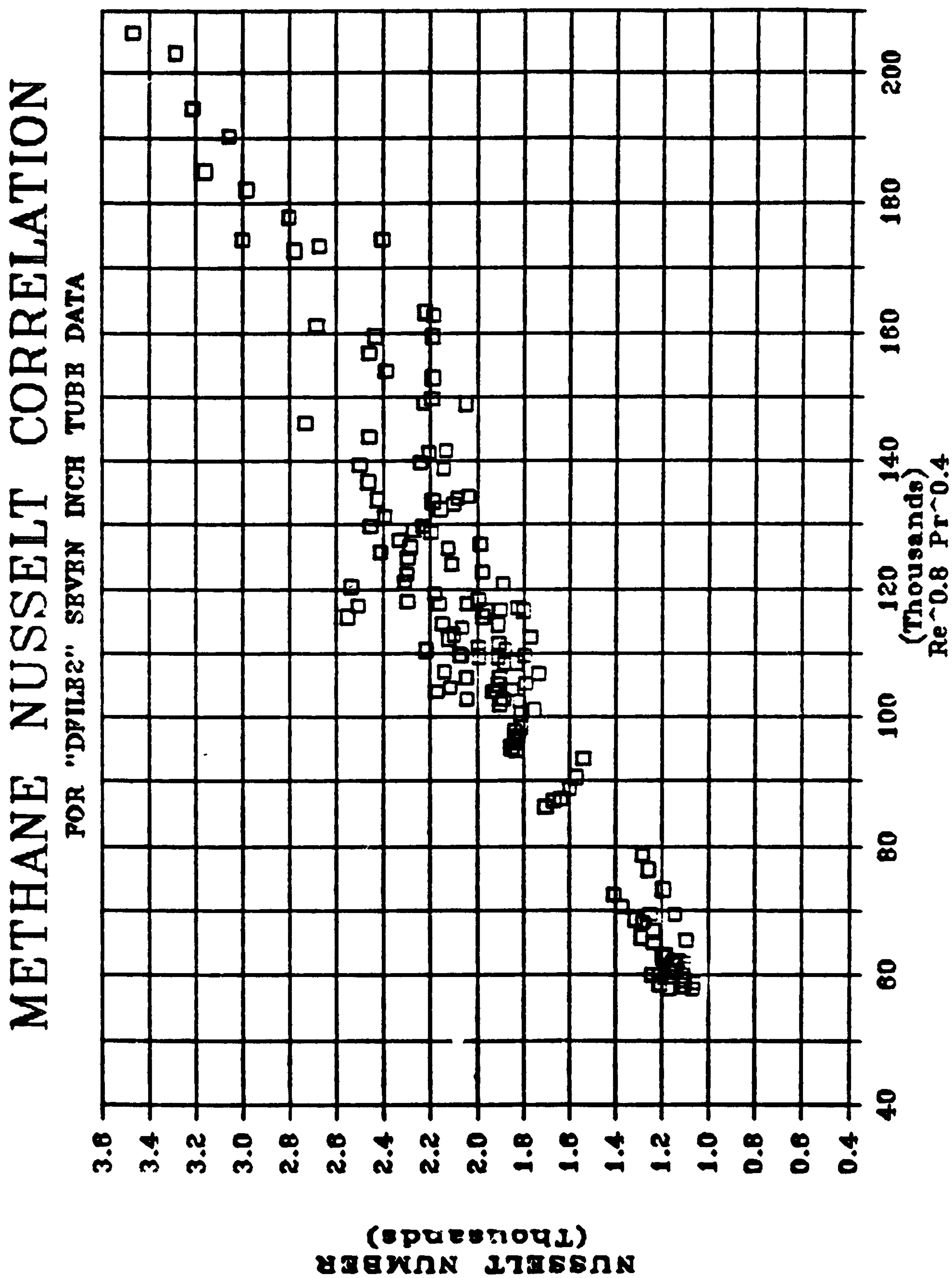


Figure 2. Dittus-Boelter Form of Nusselt Correlation

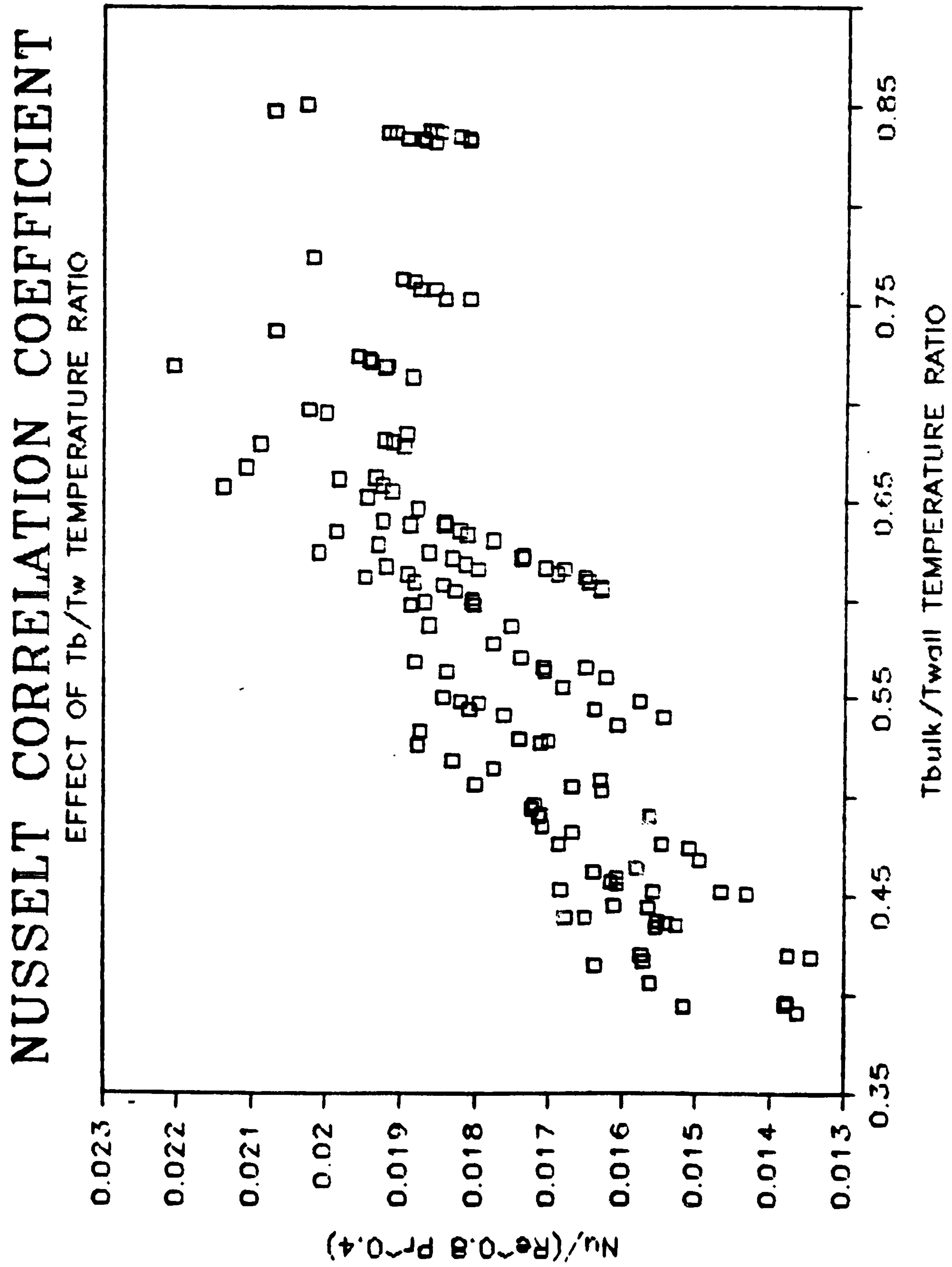


Figure 3. Nusselt Coefficient Dependence on Temperature Ratio

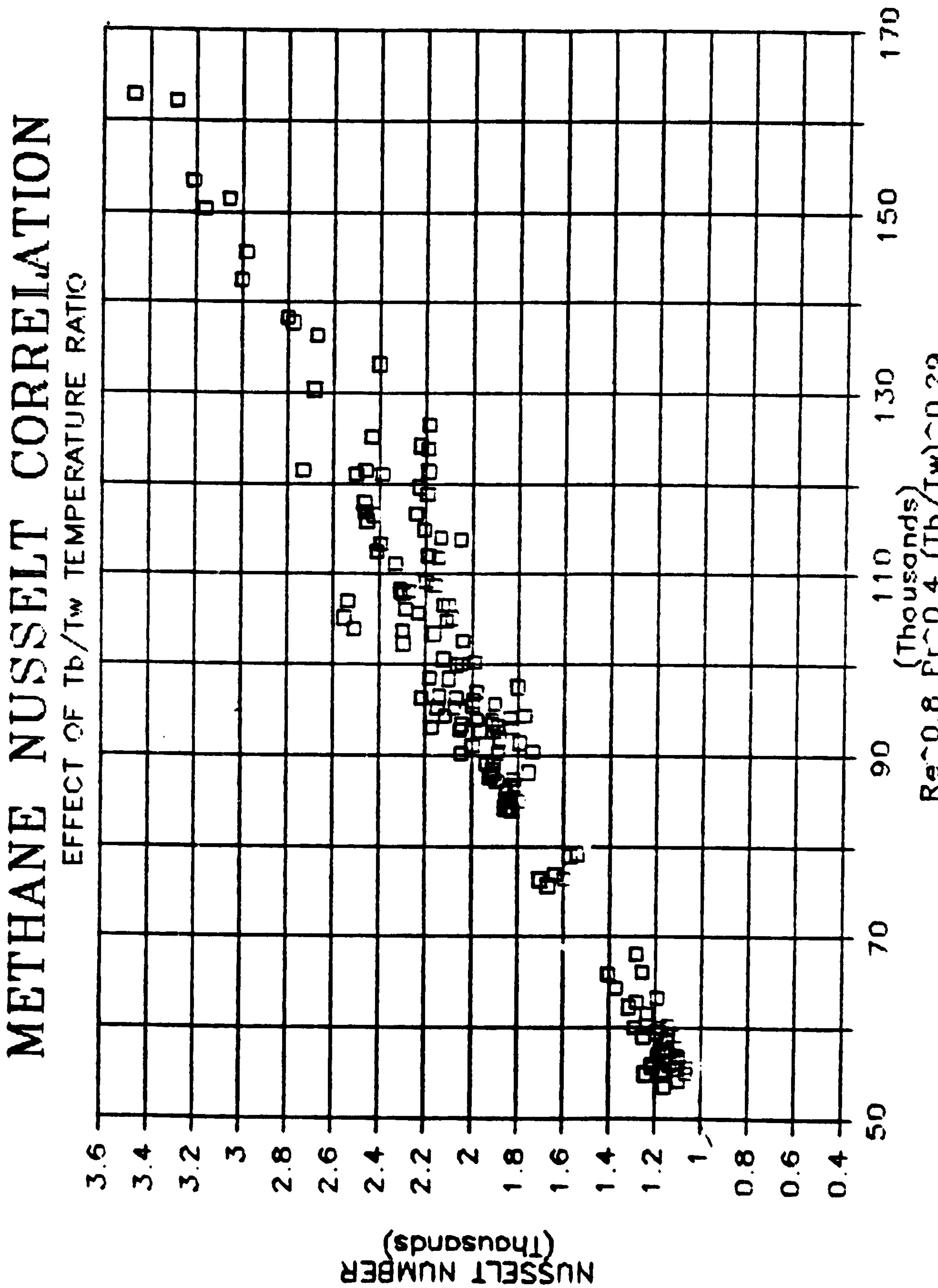


Figure 4. Nusselt Correlation with Temperature Ratio Term

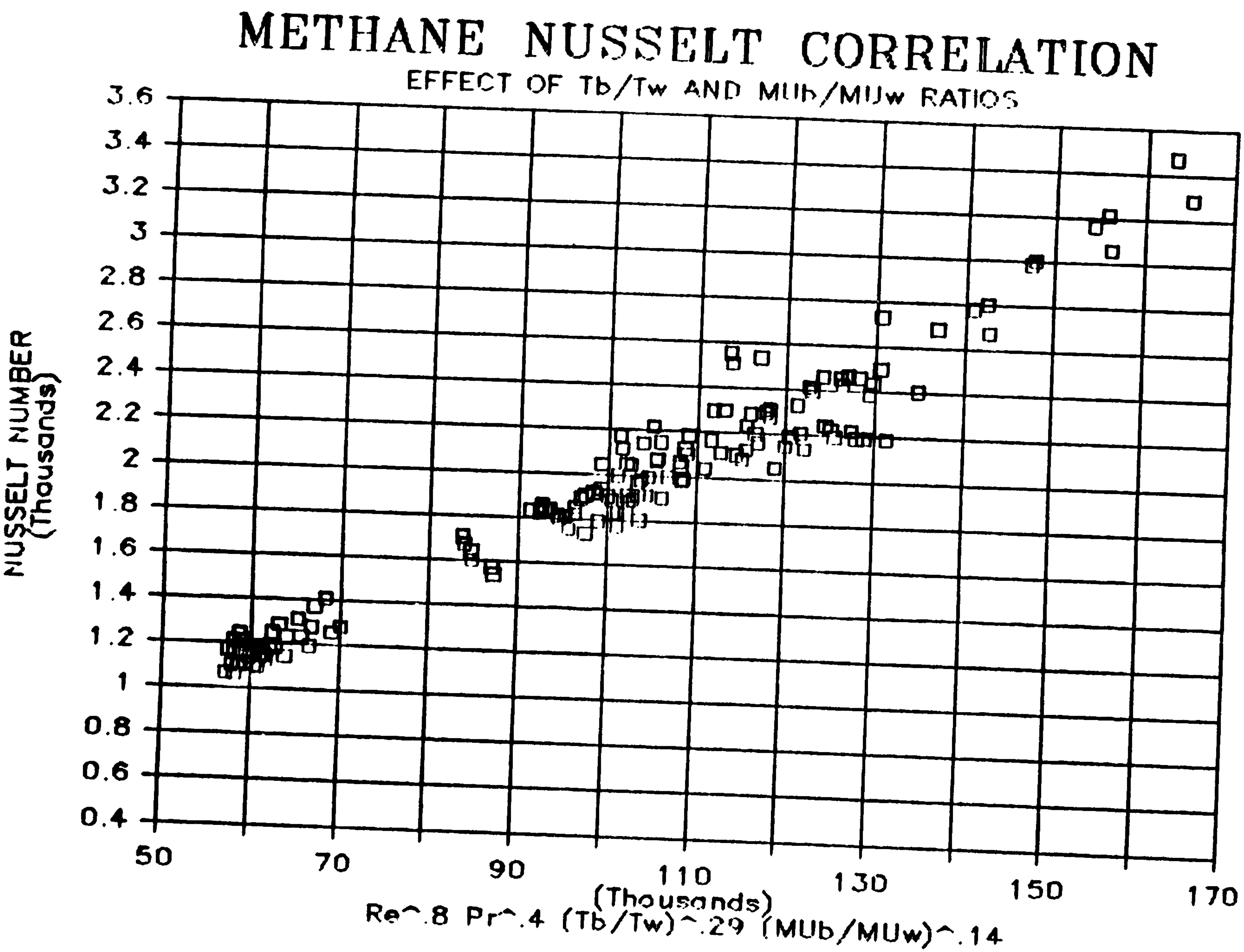


Figure 5. Nusselt Correlation with Temperature Ratio and Viscosity Ratio Terms

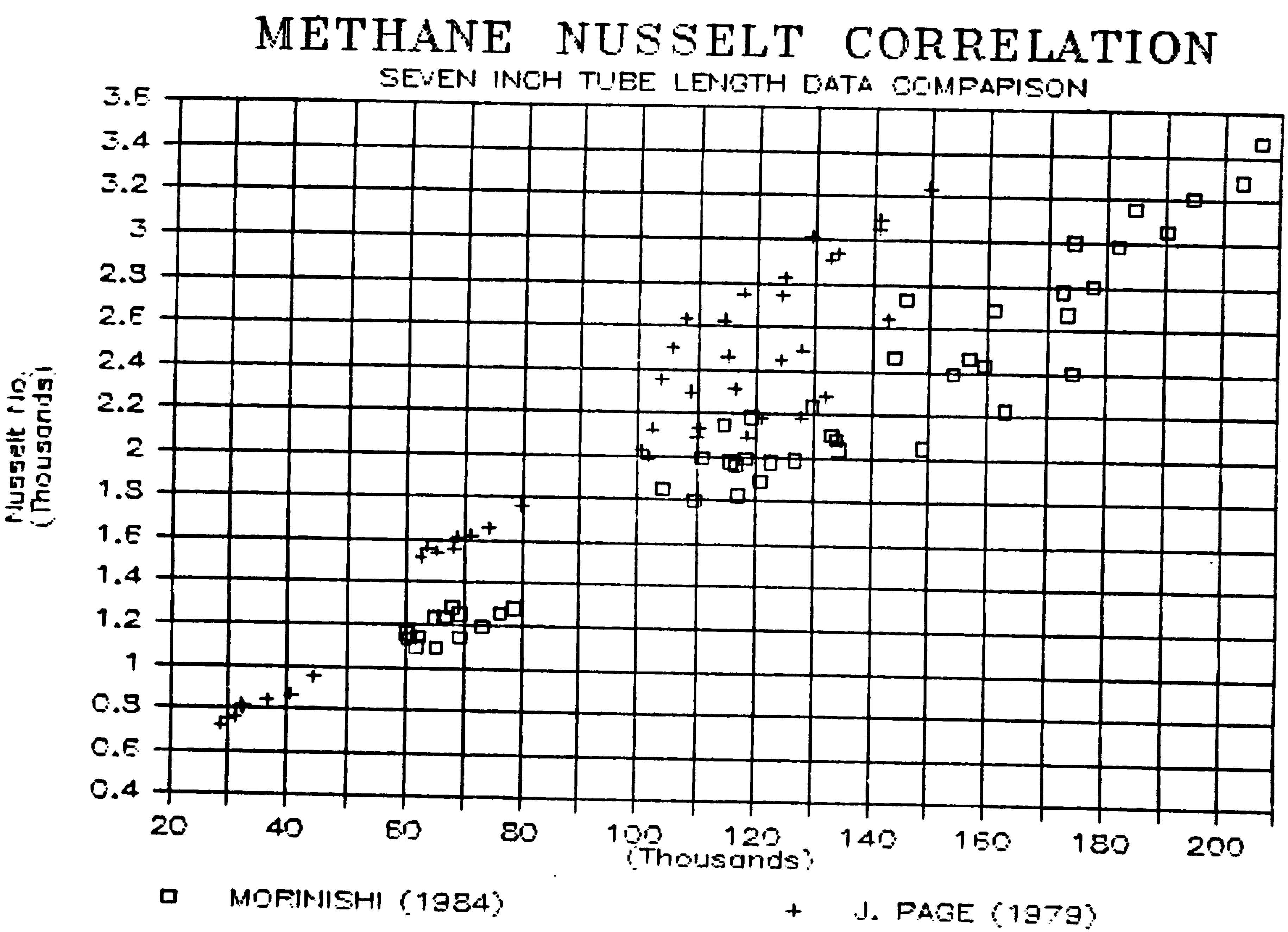
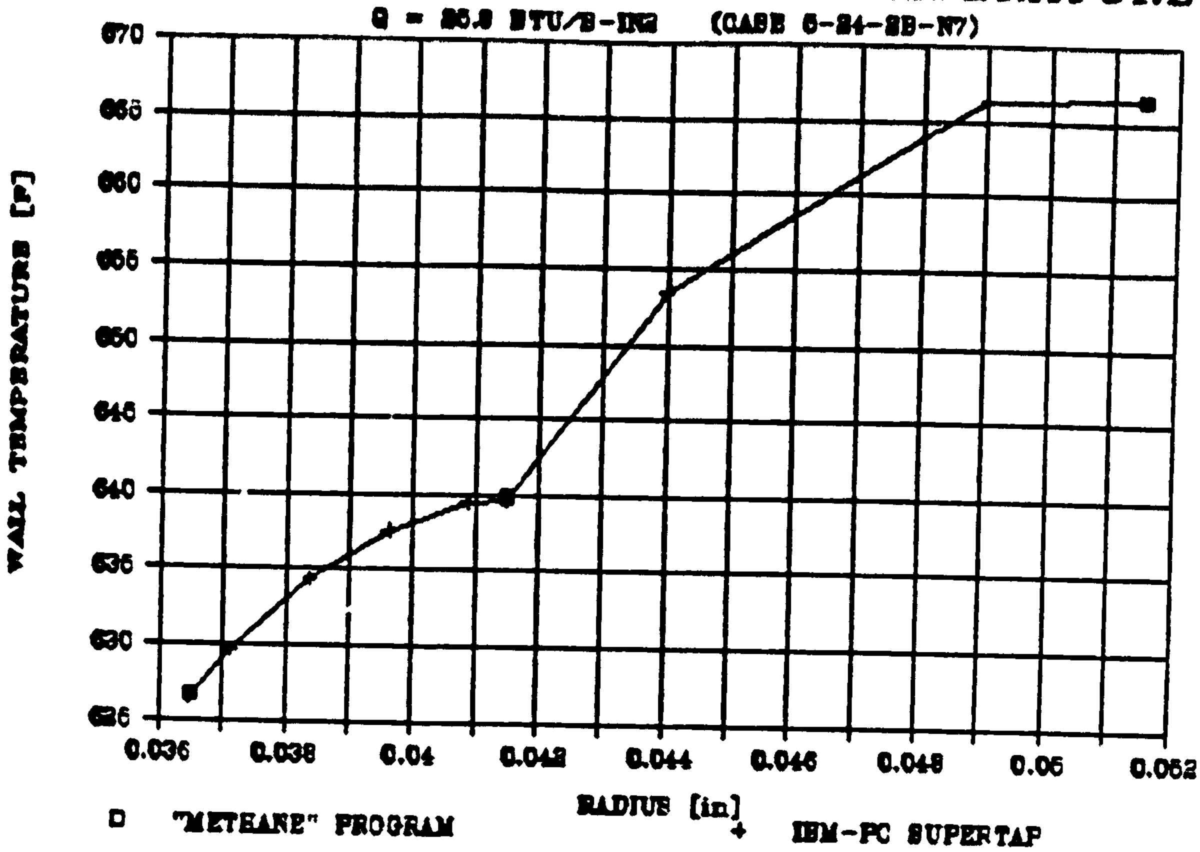


Figure 6. Comparison of Present Results with Previous Rocketdyne Methane Tests

BIMETALLIC TUBE WALL TEMPERATURE



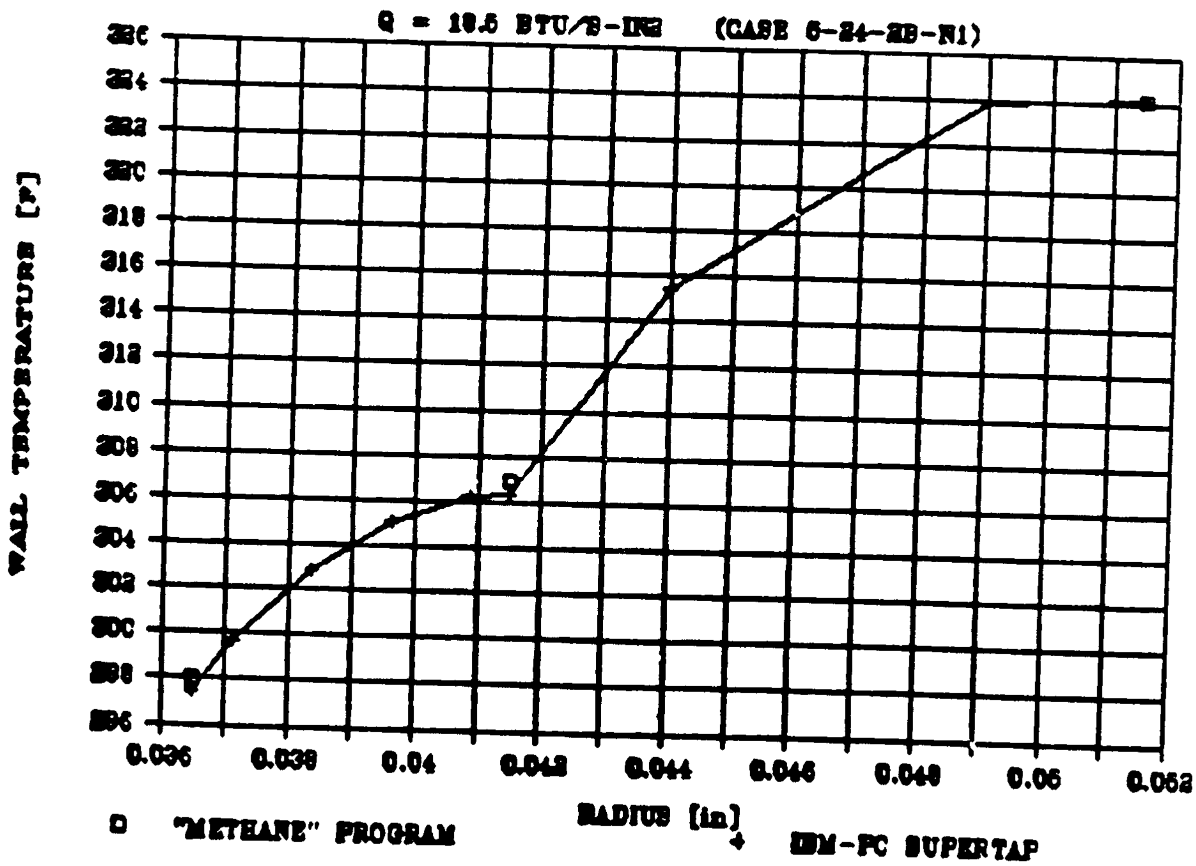


Figure 7. Comparison of the Bimetallic Tube Heat Conduction Solutions

APPENDIX

REDUCED DATA

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METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-17-38   TIME = 14:57:35   TUBE L = 7.00 [in]   # OF TC = 7

Qabse = 2.88 [KWe]   I = 906.1 [amps]   V = 3.173 [volts]   R = 3.50 [mOhms]
T u/s= -55.7 [F]   T d/s= -24.6 [F]   Pin =4966.0 [psia]   Pout = 4741.0 [psia]
T in = -56.5 [F]   Tout = -32.1 [F]   H in= 307.2   H out = 332.7 [Btu/lb]

Vol Flow = 2.37 [GPM]   Mass Flow = .1040[lb/s]   Mass Flux = 24.84[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	12.4	11.1	10.3	-59.6	-58.8	4860.6	1.627	.23550E-01
.97	13.3	19.1	17.8	17.0	-60.7	-59.8	4852.5	1.650	.21467E-01
1.91	26.2	28.1	26.7	26.0	-55.0	-54.1	4837.2	1.680	.20979E-01
4.16	57.0	34.1	32.7	31.9	-47.6	-46.7	4817.5	1.699	.21617E-01
5.02	68.8	43.3	41.9	41.1	-41.6	-40.6	4801.5	1.730	.21171E-01
6.10	83.6	47.0	45.6	44.7	-37.0	-36.0	4789.5	1.741	.21560E-01
6.84	93.7	53.7	52.2	51.4	-33.4	-32.5	4780.2	1.764	.21027E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.50	11.33	.43	868.	38.	.36	.02	.37	.00
.97	.895	.51	11.33	.44	867.	39.	.36	.02	.38	.00
1.91	1.595	.52	11.34	.45	867.	40.	.37	.02	.39	.00
4.16	1.555	.52	11.34	.45	866.	40.	.37	.02	.39	.00
5.02	.970	.53	11.35	.46	865.	41.	.38	.02	.40	.00
6.10	.910	.54	11.35	.47	865.	41.	.38	.02	.40	.00
6.84	.530	.54	11.35	.47	865.	41.	.39	.02	.40	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	181.4	.8173E+06	1.209	.851	1.30	.1173E+04	.1187E-02
.97	181.0	.8141E+06	1.211	.837	1.34	.1067E+04	.1082E-02
1.91	183.5	.8311E+06	1.210	.833	1.36	.1061E+04	.1055E-02
4.16	186.7	.8540E+06	1.203	.838	1.36	.1114E+04	.1084E-02
5.02	189.5	.8733E+06	1.197	.835	1.37	.1107E+04	.1059E-02
6.10	191.6	.8883E+06	1.195	.838	1.36	.1142E+04	.1076E-02
6.84	193.3	.9003E+06	1.192	.834	1.38	.1125E+04	.1046E-02

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-59.6	4860.6	304.624	.2663E-04	.17590E-04	.7984	19.721
.97	-60.7	4852.5	303.732	.2673E-04	.17629E-04	.7985	19.760
1.91	-55.0	4837.2	308.419	.2618E-04	.17321E-04	.8003	19.497
4.16	-47.6	4817.5	314.488	.2548E-04	.16999E-04	.8028	19.156
5.02	-41.6	4801.5	319.453	.2492E-04	.16757E-04	.8049	18.878
6.10	-37.0	4789.5	323.230	.2453E-04	.16537E-04	.8065	18.667
6.84	-33.4	4780.2	326.160	.2417E-04	.16376E-04	.8078	18.503

CALC. CHECK: Wattmeter Qe = 2.88[kw]   Sensible Qs = 2.80[kw]   Qerr = 2.58%
Meas. V = .100 [volts]   Calc. V = 3.173 [volts]   Verr *******% (NO DATA)
Meas. I ******* [amps]   Calc. I = 906.1 [amps]   Ierr = 96.85%
Meas. Tout = -25.5 [F]   Calc. Tout = -32.1 [F]   Terr = 6.6 [F]

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METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-17-3C   TIME = 14:58:29   TUBE L = 7.02 [in]   # OF TC = 7

Qabs = 3.03 [KWe]   I = 910.2 [amps]   V = 3.323 [volts]   R = 3.65 [mOhms]
T u/s= -40.8 [F]   T d/s= -7.9 [F]   Pin =4936.0 [psia]   Pout = 4715.0 [psia]
T in = -41.6 [F]   Tout = -14.3 [F]   H in= 319.4   H out = 346.5 [Btu/lb]

Vol Flow = 2.36 [GPM]   Mass Flow = .0999[lb/s]   Mass Flux = 23.88[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	31.7	30.3	29.5	-44.7	-43.8	4835.3	1.706	.23264E-01
.97	13.3	38.9	37.5	36.7	-45.6	-44.7	4827.5	1.730	.21264E-01
1.91	26.2	48.1	46.6	45.8	-39.3	-38.5	4812.8	1.761	.20894E-01
4.16	57.0	54.6	53.1	52.3	-31.3	-30.4	4793.8	1.782	.21560E-01
5.02	68.8	64.7	63.2	62.3	-24.7	-23.8	4778.4	1.816	.21087E-01
6.10	83.6	68.7	67.2	66.3	-19.7	-18.8	4766.7	1.829	.21498E-01
6.84	93.7	75.0	73.4	72.6	-15.8	-14.8	4757.6	1.850	.21165E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.52	11.34	.45	870.	40.	.37	.02	.39	.00
.97	.885	.53	11.35	.46	870.	41.	.38	.02	.40	.00
1.91	1.595	.54	11.35	.47	869.	41.	.39	.02	.40	.00
4.16	1.555	.55	11.36	.47	868.	42.	.39	.02	.41	.00
02	.970	.56	11.36	.48	868.	42.	.40	.02	.42	.00
.10	.910	.56	11.36	.49	867.	43.	.40	.02	.42	.00
6.84	.550	.57	11.37	.49	867.	43.	.40	.02	.42	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	180.5	.8297E+06	1.201	.848	1.33	.1210E+04	.1214E-02
.97	180.2	.8271E+06	1.202	.834	1.37	.1103E+04	.1109E-02
1.91	183.0	.8464E+06	1.194	.832	1.38	.1099E+04	.1087E-02
4.16	186.6	.8724E+06	1.191	.837	1.37	.1162E+04	.1118E-02
5.02	189.7	.8944E+06	1.181	.833	1.38	.1151E+04	.1090E-02
6.10	192.1	.9117E+06	1.180	.837	1.37	.1193E+04	.1109E-02
6.84	194.1	.9256E+06	1.170	.834	1.38	.1181E+04	.1090E-02

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-44.7	4835.3	316.887	.2521E-04	.16848E-04	.8027	19.049
.97	-45.6	4827.5	316.171	.2529E-04	.16894E-04	.8028	19.078
1.91	-39.3	4812.8	321.292	.2471E-04	.16661E-04	.8049	18.794
4.16	-31.3	4793.8	327.925	.2398E-04	.16256E-04	.8078	18.426
5.02	-24.7	4778.4	333.359	.2339E-04	.16044E-04	.8101	18.125
10	-19.7	4766.7	337.498	.2294E-04	.15783E-04	.8119	17.897
84	-15.8	4757.6	340.754	.2260E-04	.15706E-04	.8132	17.718

CALC. CHECK: Wattmeter Qe = 3.03[kw]   Sensible Qs = 2.86[kw]   Qerr = 5.45%
Meas. V = .100 [volts]   Calc. V = 3.323 [volts]   Verr *******%
Meas. I ******* [amps]   Calc. I = 910.2 [amps]   Ierr = 96.99%
Meas. Tout = -8.8 [F]   Calc. Tout = -14.3 [F]   Terr = 5.5 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-17-3D   TIME = 15:00:51   TUBE L = 7.02 [in]   # OF TC = 7

Qabse = 6.53 [KWe]   I =1212.4 [amps]   V = 5.382 [volts]   R = 4.44 [mOhms]
T u/s= -36.1 [F]   T d/s= 33.9 [F]   Pin =4843.0 [psia]   Pout = 4600.0 [psia]
T in = -37.0 [F]   Tout = 34.3 [F]   H in= 323.3   H out = 381.2 [Btu/lb]

Vol Flow = 2.41 [GPM]   Mass Flow = .1002[lb/s]   Mass Flux = 23.94[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	119.0	115.9	114.3	-37.0	-36.1	4739.7	3.511	.23352E-01
.97	13.3	140.5	137.3	135.6	-32.5	-31.6	4730.9	3.634	.21744E-01
1.91	26.2	163.0	159.6	157.8	-19.6	-18.6	4714.3	3.763	.21332E-01
4.16	57.0	176.9	173.4	171.6	-2.6	-1.6	4692.6	3.843	.22192E-01
5.02	68.8	201.7	198.0	196.1	11.4	12.5	4674.5	3.984	.21700E-01
6.10	83.6	214.0	210.2	208.3	22.3	23.5	4660.5	4.054	.21935E-01
6.84	93.7	226.9	223.0	221.1	31.0	32.2	4649.4	4.127	.21852E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.61	11.39	.70	1151.	62.	.76	.04	.81	.00
.97	.885	.63	11.41	.73	1149.	64.	.79	.04	.83	.00
1.91	1.595	.65	11.42	.75	1147.	66.	.82	.05	.86	.00
4.16	1.555	.67	11.43	.77	1145.	67.	.83	.05	.88	.00
.02	.970	.70	11.44	.80	1143.	69.	.86	.05	.91	.00
.10	.910	.71	11.45	.81	1142.	71.	.88	.05	.93	.00
6.84	.550	.72	11.46	.82	1141.	72.	.89	.06	.95	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	185.2	.8560E+06	1.200	.737	1.63	.1239E+04	.1206E-02
.97	187.3	.8705E+06	1.191	.718	1.63	.1162E+04	.1121E-02
1.91	193.3	.9145E+06	1.181	.713	1.56	.1183E+04	.1095E-02
4.16	201.9	.9764E+06	1.165	.724	1.46	.1287E+04	.1132E-02
5.02	209.4	.1031E+07	1.156	.719	1.39	.1313E+04	.1102E-02
6.10	215.6	.1075E+07	1.149	.722	1.36	.1372E+04	.1111E-02
6.84	220.7	.11'1E+07	1.144	.721	1.29	.1404E+04	.1105E-02

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-37.0	4739.7	323.253	.2450E-04	.16512E-04	.8086	18.611
.97	-32.5	4730.9	326.958	.2409E-04	.16389E-04	.8102	18.407
1.91	-19.6	4714.3	337.686	.2293E-04	.15803E-04	.8142	17.827
4.16	-2.6	4692.6	351.764	.2147E-04	.15106E-04	.8192	17.075
5.02	11.4	4674.5	363.464	.2033E-04	.14477E-04	.8228	16.458
.10	22.3	4660.5	372.552	.1950E-04	.14002E-04	.8249	15.986
.84	31.0	4649.4	379.782	.1887E-04	.13630E-04	.8262	15.616

CALC. CHECK: Wattmeter Qe = 6.53[kw]   Sensible Qs = 6.13[kw]   Qerr = 6.09%
Meas. V = 5.330 [volts]   Calc. V = 5.382 [volts]   Verr = .968%
Meas. I =1224.2 [amps]   Calc. I =1212.4 [amps]   Ierr = .96%
Meas. Tout = 32.7 [F]   Calc. Tout = 34.3 [F]   Terr = 1.6 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-1A   TIME = 11:28:55   TUBE L = 7.02 [in]   # OF TC = 7

Qabse = 5.15 [KWe]   I =1147.2 [amps]   V = 4.489 [volts]   R = 3.91 [mOhms]
T u/s= -65.8 [F]   T d/s= -13.0 [F]   Pin =4754.0 [psia]   Pout = 4562.0 [psia]
T in = -66.7 [F]   Tout = -13.4 [F]   H in= 298.6   H out = 342.5 [Btu/lb]

Vol Flow = 2.48 [GPM]   Mass Flow = .1098[lb/s]   Mass Flux = 26.23[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	53.5	51.2	49.9	-65.2	-64.3	4637.1	2.809	.24613E-01
.97	13.3	71.3	68.9	67.5	-60.4	-59.4	4627.1	2.902	.22873E-01
1.91	26.2	87.6	85.0	83.7	-50.6	-49.6	4609.1	2.987	.22419E-01
4.16	57.0	96.9	94.3	92.9	-38.4	-37.3	4585.7	3.036	.23325E-01
5.02	68.8	113.1	110.4	108.9	-28.7	-27.6	4566.6	3.119	.22851E-01
6.10	83.6	119.7	116.9	115.5	-21.3	-20.2	4552.1	3.153	.23249E-01
6.84	93.7	135.0	132.1	130.6	-15.6	-14.4	4540.6	3.232	.22290E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.54	11.35	.59	1095.	52.	.61	.03	.64	.00
.97	.885	.56	11.37	.61	1093.	54.	.63	.03	.67	.00
1.91	1.595	.58	11.38	.63	1092.	55.	.65	.03	.68	.00
4.16	1.555	.59	11.38	.64	1091.	56.	.66	.03	.70	.00
02	.970	.60	11.39	.66	1089.	58.	.68	.04	.72	.00
.10	.910	.61	11.39	.67	1089.	58.	.69	.04	.72	.00
6.84	.550	.63	11.40	.68	1087.	60.	.70	.04	.74	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	191.2	.8456E+06	1.226	.774	1.54	.1207E+04	.1165E-02
.97	193.5	.8607E+06	1.222	.758	1.60	.1137E+04	.1080E-02
1.91	198.1	.8918E+06	1.219	.753	1.62	.1146E+04	.1055E-02
4.16	204.2	.9332E+06	1.236	.763	1.58	.1233E+04	.1069E-02
5.02	209.3	.9678E+06	1.225	.758	1.57	.1235E+04	.1042E-02
6.10	213.4	.9953E+06	1.218	.762	1.54	.1280E+04	.1056E-02
6.84	216.7	.1018E+07	1.216	.753	1.52	.1250E+04	.1010E-02

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-65.2	4637.1	299.842	.2717E-04	.17861E-04	.8056	19.752
.97	-60.4	4627.1	303.883	.2670E-04	.17628E-04	.8072	19.524
1.91	-50.6	4609.1	311.968	.2576E-04	.17135E-04	.8104	19.072
4.16	-38.4	4585.7	322.157	.2462E-04	.16575E-04	.8319	18.501
5.02	-28.7	4566.6	330.247	.2374E-04	.16203E-04	.8363	18.047
.10	-21.3	4552.1	336.401	.2309E-04	.15908E-04	.8394	17.703
.84	-15.6	4540.6	341.253	.2258E-04	.15624E-04	.8416	17.431

CALC. CHECK: Wattmeter Qe = 5.15[kw]   Sensible Qs = 5.08[kw]   Qerr = 1.40%
Meas. V = 4.423 [volts]   Calc. V = 4.489 [volts]   Verr = 1.501%
Meas. I =1164.5 [amps]   Calc. I =1147.2 [amps]   Ierr = 1.48%
Meas. Tout = -14.1 [F]   Calc. Tout = -13.4 [F]   Terr = .8 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-1B TIME = 11:30:52 TUBE L = 7.02 [in] # OF TC = 7

Qabse = 9.65 [KWe] I =1383.9 [amps] V = 6.973 [volts] R = 5.04 [mOhms]
T u/s= -61.4 [F] T d/s= 37.1 [F] Pin =4732.0 [psia] Pout = 4523.0 [psia]
T in = -62.3 [F] Tout = 38.4 [F] H in= 302.3 H out = 384.3 [Btu/lb]

Vol Flow = 2.48 [GPM] Mass Flow = .1085[lb/s] Mass Flux = 25.92[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	156.1	151.8	149.5	-59.1	-58.1	4616.3	4.828	.23254E-01
.97	13.3	198.2	193.5	191.0	-49.8	-48.8	4605.5	5.137	.21417E-01
1.91	26.2	242.7	237.6	234.9	-32.8	-31.8	4585.8	5.464	.20488E-01
4.16	57.0	283.8	278.3	275.5	-10.5	-9.3	4559.7	5.764	.20237E-01
5.02	68.8	321.3	315.4	312.5	8.1	9.4	4537.6	6.035	.19917E-01
6.10	83.6	341.3	335.2	332.2	22.6	23.9	4520.2	6.180	.20048E-01
6.84	93.7	366.6	360.3	357.2	34.0	35.5	4506.2	6.362	.19777E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.64	11.42	.84	1310.	74.	1.05	.06	1.11	.00
.97	.885	.69	11.44	.90	1305.	79.	1.11	.07	1.18	.00
1.91	1.595	.73	11.47	.96	1301.	83.	1.18	.08	1.25	.00
4.16	1.555	.78	11.49	1.01	1296.	88.	1.24	.08	1.32	.00
5.02	.970	.82	11.52	1.06	1292.	92.	1.29	.09	1.38	.00
6.10	.910	.84	11.53	1.08	1290.	94.	1.32	.10	1.42	.00
6.84	.550	.86	11.54	1.11	1288.	96.	1.36	.10	1.46	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	191.9	.8546E+06	1.222	.658	1.81	.1160E+04	.1110E-02
.97	196.1	.8838E+06	1.220	.630	1.76	.1098E+04	.1019E-02
1.91	204.5	.9416E+06	1.228	.615	1.66	.1096E+04	.9479E-03
4.16	216.6	.1026E+07	1.204	.611	1.54	.1145E+04	.9273E-03
5.02	227.7	.1103E+07	1.192	.606	1.44	.1192E+04	.9075E-03
6.10	236.9	.1166E+07	1.183	.609	1.37	.1255E+04	.9103E-03
6.84	244.7	.1217E+07	1.174	.605	1.23	.1283E+04	.8978E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-59.1	4616.3	304.936	.2657E-04	.17566E-04	.8079	19.457
.97	-49.8	4605.5	312.584	.2569E-04	.17082E-04	.8108	19.035
1.91	-32.8	4585.8	326.757	.2412E-04	.16375E-04	.8338	18.256
4.16	-10.5	4559.7	345.432	.2214E-04	.15483E-04	.8419	17.238
5.02	8.1	4537.6	361.087	.2059E-04	.14631E-04	.8466	16.396
6.10	22.6	4520.2	373.209	.1948E-04	.13990E-04	.8495	15.756
6.84	34.0	4506.2	382.845	.1866E-04	.13506E-04	.8497	15.255

CALC. CHECK: Wattmeter Qe = 9.65[kw] Sensible Qs = 9.39[kw] Qerr = 2.70%
Meas. V = 6.895 [volts] Calc. V = 6.973 [volts] Verr = 1.131%
Meas. I =1399.6 [amps] Calc. I =1383.9 [amps] Ierr = 1.12%
Meas. Tout = 35.7 [F] Calc. Tout = 38.4 [F] Terr = 2.7 [F]

ORIGINAL ... OF POOR QUALITY

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-2C   TIME = 13:54:40   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =14.45 [KWe]   I =1810.3 [amps]   V = 7.982 [volts]   R = 4.41 [mOhms]
T u/s=-130.9 [F]   T d/s= -42.0 [F]   Pin =3914.0 [psia]   Pout = 3345.0 [psia]
T in =-133.1 [F]   Tout = -53.1 [F]   H in= 241.4   H out = 319.0 [Btu/lb]

Vol Flow = 3.93 [GPM]   Mass Flow = .1947[lb/s]   Mass Flux = 46.53[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	87.1	81.0	77.6	-130.3	-127.9	3589.3	7.263	.35340E-01
.97	13.3	122.3	115.7	112.1	-122.7	-120.2	3561.2	7.705	.33174E-01
1.91	26.2	168.0	160.7	156.8	-108.9	-106.2	3509.7	8.276	.31475E-01
4.16	57.0	173.6	166.2	162.2	-91.1	-88.2	3441.2	8.347	.33330E-01
5.02	68.8	233.2	224.8	220.5	-76.6	-73.5	3383.4	9.084	.30899E-01
6.10	83.6	257.9	249.1	244.6	-65.4	-62.0	3337.5	9.389	.30618E-01
6.84	93.7	282.5	273.3	268.7	-56.4	-53.0	3300.4	9.691	.30132E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.56	11.37	.97	1725.	85.	1.59	.08	1.67	.00
.97	.885	.60	11.40	1.03	1720.	90.	1.68	.09	1.77	.00
1.91	1.595	.65	11.42	1.11	1713.	97.	1.80	.10	1.90	.00
4.16	1.555	.65	11.43	1.12	1713.	98.	1.81	.10	1.91	.00
02	.970	.71	11.46	1.21	1704.	106.	1.96	.12	2.08	.00
.10	.910	.74	11.48	1.26	1701.	109.	2.02	.13	2.15	.00
6.84	.550	.76	11.49	1.30	1698.	113.	2.08	.14	2.22	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	305.3	.1254E+07	1.317	.613	2.14	.1500E+04	.9084E-03
.97	311.0	.1311E+07	1.297	.590	2.19	.1443E+04	.8486E-03
1.91	322.3	.1354E+07	1.345	.569	2.18	.1450E+04	.7959E-03
4.16	338.9	.1483E+07	1.328	.593	2.01	.1626E+04	.8261E-03
5.02	354.6	.1598E+07	1.335	.563	1.89	.1602E+04	.7504E-03
6.10	368.4	.1696E+07	1.346	.560	1.79	.1667E+04	.7303E-03
6.84	380.4	.1777E+07	1.356	.554	1.71	.1707E+04	.7087E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-130.3	3589.3	243.782	.3250E-04	.20632E-04	.8362	21.947
.97	-122.7	3561.2	250.197	.3109E-04	.20138E-04	.8403	21.543
1.91	-108.9	3509.7	261.994	.3009E-04	.19016E-04	.8499	20.786
4.16	-91.1	3441.2	277.450	.2749E-04	.17953E-04	.8672	19.767
5.02	-76.6	3383.4	290.319	.2550E-04	.16900E-04	.8850	18.895
10	-65.4	3337.5	300.557	.2404E-04	.16091E-04	.9011	18.187
84	-56.4	3300.4	308.737	.2293E-04	.15461E-04	.9139	17.612

CALC. CHECK: Wattmeter Qe =14.45[kw]   Sensible Qs =15.95[kw]   Qerr = 10.40%
Meas. V = 7.950 [volts]   Calc. V = 7.982 [volts]   Verr = .400%
Meas. I =1817.5 [amps]   Calc. I =1810.3 [amps]   Ierr = .40%
Meas. Tout = -45.2 [F]   Calc. Tout = -53.1 [F]   Terr = 7.9 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-3A TIME = 14:36:34 TUBE L = 7.00 [in] # OF TC = 7

Qabse = 8.05 [KWe] I =1515.3 [amps] V = 5.312 [volts] R = 3.51 [mOhms]
T u/s=-112.9 [F] T d/s= -61.4 [F] Pin =4445.0 [psia] Pout = 3849.0 [psia]
T in =-115.3 [F] Tout = -68.3 [F] H in= 257.5 H out = 300.5 [Btu/lb]

Vol Flow = 4.00 [GPM] Mass Flow = .1937[lb/s] Mass Flux = 46.28[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	5.8	2.3	.3	-113.5	-111.0	4118.9	4.415	.39661E-01
.97	13.3	16.6	13.0	11.0	-108.8	-106.2	4092.4	4.512	.38500E-01
1.91	26.2	36.5	32.7	30.5	-100.7	-98.0	4044.7	4.692	.36501E-01
4.16	57.0	37.5	33.7	31.5	-90.2	-87.4	3982.7	4.701	.39528E-01
5.02	68.8	62.4	58.3	56.0	-81.7	-78.8	3931.9	4.925	.36522E-01
6.10	83.6	70.8	66.6	64.3	-75.2	-72.2	3893.0	5.001	.36627E-01
6.84	93.7	81.6	77.3	74.9	-70.2	-67.1	3862.7	5.097	.35882E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.49	11.33	.71	1453.	62.	.97	.04	1.01	.00
.97	.885	.50	11.33	.72	1452.	64.	.99	.04	1.03	.00
1.91	1.595	.52	11.34	.75	1449.	66.	1.03	.05	1.08	.00
4.16	1.555	.52	11.34	.75	1449.	66.	1.03	.05	1.08	.00
5.02	.970	.54	11.36	.79	1446.	69.	1.08	.05	1.13	.00
6.10	.910	.55	11.36	.80	1445.	70.	1.09	.05	1.15	.00
6.84	.530	.56	11.37	.81	1444.	72.	1.11	.06	1.17	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	309.4	.1333E+07	1.212	.753	1.43	.1682E+04	.1042E-02
.97	312.9	.1276E+07	1.320	.746	1.56	.1699E+04	.1008E-02
1.91	319.4	.1315E+07	1.299	.733	1.63	.1623E+04	.9503E-03
4.16	328.4	.1368E+07	1.294	.752	1.58	.1805E+04	.1019E-02
5.02	336.2	.1422E+07	1.296	.733	1.67	.1719E+04	.9333E-03
6.10	342.6	.1465E+07	1.300	.734	1.68	.1769E+04	.9289E-03
6.84	347.8	.1501E+07	1.301	.729	1.69	.1765E+04	.9043E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-113.5	4118.9	258.985	.3043E-04	.20656E-04	.8225	21.543
.97	-108.8	4092.4	262.820	.3176E-04	.19845E-04	.8249	21.301
1.91	-100.7	4044.7	269.613	.3084E-04	.19699E-04	.8299	20.867
4.16	-90.2	3982.7	278.377	.2963E-04	.19181E-04	.8378	20.297
5.02	-81.7	3931.9	285.543	.2852E-04	.18612E-04	.8455	19.823
6.10	-75.2	3893.0	291.068	.2767E-04	.18140E-04	.8520	19.454
6.84	-70.2	3862.7	29[illegible].366	.2702E-04	.17806E-04	.8573	19.165

CALC. CHECK: Wattmeter Qe = 8.05[kw] Sensible Qs = 8.79[kw] Qerr = 9.16%
Meas. V = 5.239 [volts] Calc. V = 5.312 [volts] Verr = 1.392%
Meas. I =1536.5 [amps] Calc. I =1515.3 [amps] Ierr = 1.38%
Meas. Tout = -64.2 [F] Calc. Tout = -68.3 [F] Terr = 4.1 [F]

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METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-3A   TIME = 14:36:42   TUBE L = 7.02 [in]   # OF TC = 7

Qabse = 8.08 [KWe]   I =1513.7 [amps]   V = 5.334 [volts]   R = 3.52 [mOhms]
T u/s=-113.1 [F]   T d/s= -61.4 [F]   Pin =4439.0 [psia]   Pout = 3848.0 [psia]
T in =-115.4 [F]   Tout = -68.3 [F]   H in= 257.3   H out = 300.5 [Btu/lb]

Vol Flow = 3.99 [GPM]   Mass Flow = .1934[lb/s]   Mass Flux = 46.21[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	6.1	2.6	.6	-113.7	-111.2	4113.9	4.409	.39427E-01
.97	13.3	17.5	13.9	11.8	-109.0	-106.4	4087.5	4.511	.38135E-01
1.91	26.2	37.1	33.3	31.1	-100.9	-98.2	4039.9	4.688	.36246E-01
4.16	57.0	38.5	34.7	32.5	-90.4	-87.6	3978.2	4.701	.39137E-01
5.02	68.8	64.0	59.9	57.6	-81.9	-79.0	3927.4	4.929	.36085E-01
6.10	83.6	72.8	68.6	66.3	-75.4	-72.4	3888.7	5.008	.36120E-01
6.84	93.7	83.1	78.8	76.4	-70.2	-67.2	3858.1	5.100	.35515E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.49	11.33	.70	1451.	62.	.97	.04	1.01	.00
.97	.885	.50	11.33	.72	1450.	64.	.99	.04	1.03	.00
1.91	1.595	.52	11.34	.75	1448.	66.	1.03	.05	1.08	.00
4.16	1.555	.52	11.34	.75	1447.	66.	1.03	.05	1.08	.00
02	.970	.55	11.36	.79	1444.	69.	1.08	.05	1.13	.00
.10	.910	.55	11.37	.80	1443.	70.	1.10	.05	1.15	.00
6.84	.550	.57	11.37	.82	1442.	72.	1.11	.06	1.17	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	308.8	.1328E+07	1.213	.752	1.44	.1672E+04	.1037E-02
.97	312.3	.1274E+07	1.321	.744	1.57	.1683E+04	.1000E-02
1.91	318.8	.1312E+07	1.300	.731	1.64	.1611E+04	.9450E-03
4.16	327.8	.1366E+07	1.292	.750	1.59	.1784E+04	.1011E-02
5.02	335.6	.1420E+07	1.295	.730	1.68	.1697E+04	.9233E-03
6.10	342.0	.1463E+07	1.299	.731	1.69	.1743E+04	.9173E-03
6.84	347.3	.1499E+07	1.302	.727	1.70	.1749E+04	.8962E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-113.7	4113.9	258.815	.3048E-04	.20662E-04	.8226	21.548
.97	-109.0	4087.5	262.653	.3179E-04	.19851E-04	.8250	21.306
1.91	-100.9	4039.9	269.452	.3086E-04	.19706E-04	.8300	20.872
4.16	-90.4	3978.2	278.226	.2963E-04	.19214E-04	.8381	20.301
5.02	-81.9	3927.4	285.406	.2852E-04	.18622E-04	.8457	19.826
10	-75.4	3888.7	290.946	.2767E-04	.18149E-04	.8521	19.456
84	-70.2	3858.1	295.316	.2700E-04	.17792E-04	.8576	19.162

CALC. CHECK: Wattmeter Qe = 8.08[kw]   Sensible Qs = 8.81[kw]   Qerr = 9.10%
Meas. V = 5.301 [volts]   Calc. V = 5.334 [volts]   Verr = .629%
Meas. I =1523.3 [amps]   Calc. I =1513.7 [amps]   Ierr = .63%
Meas. Tout = -64.2 [F]   Calc. Tout = -68.3 [F]   Terr = 4.1 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-3B   TIME = 14:38:16   TUBE L = 7.00 [in]   # OF TC = 7

Qabse =13.18 [KWe]   I =1767.3 [amps]   V = 7.455 [volts]   R = 4.22 [mOhms]
T u/s=-109.8 [F]   T d/s= -30.3 [F]   Pin =4380.0 [psia]   Pout = 3746.0 [psia]
T in =-112.2 [F]   Tout = -37.3 [F]   H in= 259.9   H out = 327.4 [Btu/lb]

Vol Flow = 4.05 [GPM]   Mass Flow = .1946[lb/s]   Mass Flux = 46.48[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	79.0	73.3	70.1	-109.5	-106.9	4046.7	6.837	.38622E-01
.97	13.3	102.7	96.7	93.3	-102.3	-99.7	4018.2	7.122	.36901E-01
1.91	26.2	146.7	140.0	136.4	-89.4	-86.6	3966.0	7.648	.34304E-01
4.16	57.0	141.7	135.1	131.5	-72.7	-69.7	3897.2	7.590	.37727E-01
5.02	68.8	195.6	188.2	184.3	-59.2	-55.9	3839.6	8.230	.34269E-01
6.10	83.6	219.5	211.7	207.6	-48.5	-45.1	3794.3	8.513	.33686E-01
6.84	93.7	2[illegible]5.7	228.6	224.5	-40.3	-36.7	3758.4	8.716	.33375E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.56	11.37	.94	1685.	82.	1.49	.07	1.57	.00
.97	.885	.58	11.38	.98	1682.	86.	1.55	.08	1.63	.00
1.91	1.595	.63	11.41	1.05	1676.	92.	1.66	.09	1.75	.00
4.16	1.555	.62	11.41	1.04	1676.	91.	1.65	.09	1.74	.00
02	.970	.68	11.44	1.13	1669.	98.	1.78	.11	1.89	.00
.10	.910	.70	11.45	1.17	1666.	102.	1.84	.11	1.95	.00
6.84	.530	.72	11.47	1.19	1663.	104.	1.88	.12	2.00	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	314.3	.1279E+07	1.325	.661	1.93	.1703E+04	.1005E-02
.97	319.9	.1312E+07	1.304	.646	1.99	.1637E+04	.9561E-03
1.91	330.7	.1381E+07	1.294	.621	2.01	.1573E+04	.8795E-03
4.16	346.2	.1484E+07	1.301	.655	1.88	.1837E+04	.9512E-03
5.02	360.4	.1578E+07	1.305	.622	1.80	.1753E+04	.8511E-03
6.10	372.6	.1657E+07	1.307	.616	1.75	.1792E+04	.8276E-03
6.84	382.9	.1724E+07	1.307	.613	1.67	.1832E+04	.8134E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-109.5	4046.7	262.176	.3184E-04	.19862E-04	.8265	21.295
.97	-102.3	4018.2	268.150	.3103E-04	.19750E-04	.8303	20.925
1.91	-89.4	3966.0	279.048	.2948E-04	.19108E-04	.8391	20.241
4.16	-72.7	3897.2	293.201	.2744E-04	.17989E-04	.8533	19.333
5.02	-59.2	3839.6	304.875	.2581E-04	.17129E-04	.8662	18.573
10	-48.5	3794.3	314.121	.2457E-04	.16464E-04	.8757	17.967
84	-40.3	3758.4	321.436	.2362E-04	.15959E-04	.8827	17.483

CALC. CHECK: Wattmeter Qe =13.18[kw]   Sensible Qs =13.84[kw]   Qerr = 5.06%
Meas. V = 7.453 [volts]   Calc. V = 7.455 [volts]   Verr = .031%
Meas. I =1767.9 [amps]   Calc. I =1767.3 [amps]   Ierr = .03%
Meas. Tout = -33.6 [F]   Calc. Tout = -37.3 [F]   Terr = 3.6 [F]

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METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-3C   TIME = 14:39:19   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =16.37 [KWe]   I =1863.4 [amps]   V = 8.788 [volts]   R = 4.72 [mOhms]
T u/s=-109.7 [F]   T d/s= -13.6 [F]   Pin =4299.0 [psia]   Pout = 3631.0 [psia]
T in =-112.2 [F]   Tout = -21.0 [F]   H in= 259.8   H out = 342.3 [Btu/lb]

Vol Flow = 4.09 [GPM]   Mass Flow = .1959[lb/s]   Mass Flux = 46.80[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	120.0	113.0	109.3	-109.0	-106.3	3959.8	8.116	.37653E-01
.97	13.3	153.9	146.4	142.4	-100.5	-97.8	3930.0	8.564	.35667E-01
1.91	26.2	217.3	208.7	204.3	-84.9	-82.0	3874.8	9.396	.32828E-01
4.16	57.0	211.3	202.8	198.4	-64.8	-61.6	3801.0	9.320	.35849E-01
5.02	68.8	289.9	280.1	275.1	-48.4	-44.9	3738.2	10.342	.32316E-01
6.10	83.6	329.9	319.4	314.2	-35.4	-31.6	3687.7	10.857	.31400E-01
6.84	93.7	361.8	350.8	345.3	-25.0	-20.9	3646.6	11.266	.30763E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.60	11.39	1.05	1771.	92.	1.77	.09	1.86	.00
.97	.885	.63	11.41	1.11	1766.	97.	1.86	.10	1.96	.00
1.91	1.595	.69	11.45	1.22	1757.	107.	2.03	.12	2.15	.00
4.16	1.555	.69	11.45	1.21	1758.	106.	2.02	.12	2.14	.00
02	.970	.77	11.50	1.34	1747.	117.	2.22	.15	2.37	.00
.10	.910	.81	11.52	1.41	1741.	122.	2.33	.16	2.49	.00
6.84	.550	.84	11.54	1.46	1737.	127.	2.41	.18	2.58	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	318.0	.1296E+07	1.328	.617	2.10	.1668E+04	.9695E-03
.97	324.7	.1342E+07	1.305	.597	2.09	.1598E+04	.9128E-03
1.91	338.3	.1433E+07	1.298	.565	2.01	.1541E+04	.8287E-03
4.16	358.2	.1566E+07	1.307	.600	1.84	.1812E+04	.8857E-03
5.02	377.1	.1688E+07	1.310	.560	1.73	.1735E+04	.7841E-03
6.10	393.9	.1795E+07	1.311	.548	1.64	.1771E+04	.7528E-03
6.84	408.7	.1887E+07	1.304	.540	1.54	.1802E+04	.7319E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-109.0	3959.8	262.452	.3165E-04	.19770E-04	.8298	21.197
.97	-100.5	3930.0	269.548	.3056E-04	.19549E-04	.8348	20.757
1.91	-84.9	3874.8	282.743	.2861E-04	.18659E-04	.8464	19.925
4.16	-64.8	3801.0	299.961	.2619E-04	.17332E-04	.8648	18.818
5.02	-48.4	3738.2	314.381	.2428E-04	.16320E-04	.8806	17.874
10	-35.4	3687.7	326.029	.2284E-04	.15527E-04	.8911	17.109
84	-25.0	3646.6	335.433	.2173E-04	.14956E-04	.8980	16.491

CALC. CHECK: Wattmeter Qe =16.37[kw]   Sensible Qs =17.05[kw]   Qerr = 4.14%
Meas. V = 8.777 [volts]   Calc. V = 8.788 [volts]   Verr = .117%
Meas. I =1865.6 [amps]   Calc. I =1863.4 [amps]   Ierr = .12%
Meas. Tout = -17.3 [F]   Calc. Tout = -21.0 [F]   Terr = 3.7 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-4A TIME = 15:38:00 TUBE L = 7.02 [in] # OF TC = 7

Qobse =14.13 [KWe] I =1864.6 [amps] V = 7.575 [volts] R = 4.06 [mOhms]
T u/s=-113.3 [F] T d/s= -37.6 [F] Pin =4500.0 [psia] Pout = 3692.0 [psia]
T in =-116.3 [F] Tout = -45.0 [F] H in= 256.5 H out = 320.4 [Btu/lb]

Vol Flow = 4.53 [GPM] Mass Flow = .2199[lb/s] Mass Flux = 52.53[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	72.4	66.2	62.8	-113.7	-110.5	4082.1	7.492	.43241E-01
.97	13.3	91.5	85.0	81.4	-106.8	-103.4	4047.1	7.747	.41922E-01
1.91	26.2	124.4	117.4	113.5	-94.3	-90.8	3982.7	8.184	.40053E-01
4.16	57.0	111.9	105.1	101.3	-78.6	-74.8	3898.0	8.020	.45538E-01
5.02	68.8	172.8	165.0	160.8	-65.8	-61.7	3827.1	8.824	.39657E-01
6.10	83.6	190.6	182.5	178.2	-55.7	-51.4	3771.5	9.060	.39455E-01
6.84	93.7	197.4	189.1	184.8	-47.9	-43.5	3727.0	9.149	.40081E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.55	11.37	.97	1779.	86.	1.64	.08	1.72	.00
.97	.885	.57	11.38	1.01	1776.	88.	1.69	.08	1.78	.00
1.91	1.595	.60	11.40	1.06	1771.	93.	1.78	.05	1.88	.00
4.16	1.555	.59	11.39	1.04	1773.	91.	1.75	.09	1.84	.00
02	.970	.65	11.43	1.15	1764.	100.	1.91	.11	2.02	.00
.10	.910	.67	11.44	1.18	1762.	103.	1.96	.11	2.08	.00
6.84	.550	.67	11.44	1.19	1761.	104.	1.98	.12	2.10	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	351.4	.1509E+07	1.215	.662	1.80	.1833E+04	.9994E-03
.97	357.4	.1460E+07	1.315	.652	1.97	.1852E+04	.9646E-03
1.91	369.0	.1530E+07	1.296	.638	2.00	.1810E+04	.9125E-03
4.16	385.3	.1641E+07	1.297	.679	1.85	.2172E+04	.1021E-02
5.02	400.3	.1743E+07	1.306	.635	1.84	.1993E+04	.8754E-03
6.10	413.3	.1830E+07	1.312	.633	1.76	.2064E+04	.8602E-03
6.84	424.3	.1903E+07	1.314	.639	1.71	.2165E+04	.8654E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-113.7	4082.1	258.723	.3049E-04	.20663E-04	.8237	21.525
.97	-106.8	4047.1	264.488	.3152E-04	.19831E-04	.8274	21.163
1.91	-94.3	3982.7	274.865	.3008E-04	.19390E-04	.8356	20.501
4.16	-78.6	3898.0	288.187	.2804E-04	.18368E-04	.8494	19.630
5.02	-65.8	3827.1	299.170	.2640E-04	.17434E-04	.8624	18.896
10	-55.7	3771.5	307.936	.2514E-04	.16741E-04	.8732	18.304
34	-47.9	3727.0	314.872	.2418E-04	.16219E-04	.8817	17.829

CALC. CHECK: Wattmeter Qe =14.13[kw] Sensible Qs =14.82[kw] Qerr = 4.89%
Meas. V = 7.607 [volts] Calc. V = 7.575 [volts] Verr = .413%
Meas. I =1856.9 [amps] Calc. I =1864.6 [amps] Ierr = .41%
Meas. Tout = -41.7 [F] Calc. Tout = -45.0 [F] Terr = 3.3 [F]

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METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-18-4B TIME = 15:39:27 TUBE L = 7.02 [in] # OF TC = 7

Qabse =18.38 [KWe] I =2008.6 [amps] V = 9.148 [volts] R = 4.55 [mOhms]
T u/s=-112.6 [F] T d/s= -19.2 [F] Pin =4443.0 [psia] Pout = 3569.0 [psia]
T in =-115.8 [F] Tout = -26.1 [F] H in= 256.9 H out = 336.6 [Btu/lb]

Vol Flow = 4.63 [GPM] Mass Flow = .2240[lb/s] Mass Flux = 53.52[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIA. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	122.6	114.6	110.2	-112.5	-109.2	4007.6	9.410	.42894E-01
.97	13.3	149.8	141.3	136.6	-104.0	-100.4	3969.9	9.825	.41444E-01
1.91	26.2	198.2	188.7	183.7	-88.5	-84.7	3899.6	10.559	.39340E-01
4.16	57.0	180.8	171.7	166.8	-68.8	-64.7	3806.0	10.299	.44498E-01
5.02	68.8	271.0	260.1	254.5	-52.8	-48.3	3726.2	11.658	.38496E-01
6.10	83.6	303.3	291.8	285.9	-40.0	-35.2	3662.0	12.138	.37799E-01
6.84	93.7	319.5	307.7	301.7	-30.0	-24.8	3609.7	12.380	.37919E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.59	11.40	1.13	1909.	99.	2.05	.11	2.16	.00
.97	.885	.62	11.41	1.18	1905.	104.	2.14	.12	2.25	.00
1.91	1.595	.67	11.44	1.27	1897.	111.	2.29	.13	2.42	.00
4.16	1.555	.65	11.43	1.24	1900.	109.	2.23	.13	2.36	.00
02	.970	.74	11.49	1.40	1886.	122.	2.51	.16	2.67	.00
.10	.910	.78	11.51	1.46	1881.	127.	2.61	.18	2.78	.00
6.84	.550	.79	11.52	1.49	1879.	130.	2.66	.18	2.84	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	360.0	.1553E+07	1.210	.609	2.00	.1822E+04	.9693E-03
.97	367.7	.1508E+07	1.311	.597	2.12	.1841E+04	.9313E-03
1.91	382.9	.1611E+07	1.294	.577	2.01	.1818E+04	.8719E-03
4.16	405.0	.1762E+07	1.304	.624	1.86	.2217E+04	.9648E-03
5.02	426.1	.1902E+07	1.314	.570	1.76	.2045E+04	.8185E-03
6.10	445.2	.2027E+07	1.315	.563	1.67	.2112E+04	.7924E-03
6.84	461.8	.2133[illegible]+07	1.311	.565	1.59	.2201E+04	.7871E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-112.5	4007.6	259.547	.3019E-04	.20626E-04	.8268	21.409
.97	-104.0	3969.9	266.692	.3110E-04	.19721E-04	.8315	20.962
1.91	-88.5	3899.6	279.751	.2910E-04	.18956E-04	.8431	20.129
4.16	-68.8	3806.0	296.530	.2661E-04	.17584E-04	.8618	19.028
5.02	-52.8	3726.2	310.591	.2464E-04	.16487E-04	.8788	18.085
10	-40.0	3662.0	322.031	.2313E-04	.15678E-04	.8913	17.310
84	-30.0	3609.7	331.169	.2198E-04	.15089E-04	.9001	16.688

CALC. CHECK: Wattmeter Qe =18.38[kw] Sensible Qs =18.85[kw] Qerr = 2.59%
Meas. V = 9.168 [volts] Calc. V = 9.148 [volts] Verr = .222%
Meas. I =2004.2 [amps] Calc. I =2008.6 [amps] Ierr = .22%
Meas. Tout = -23.9 [F] Calc. Tout = -26.1 [F] Terr = 2.2 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-1A   TIME = 10:45:08   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =13.18 [KWe]   I =1886.4 [amps]   V = 6.984 [volts]   R = 3.70 [mOhms]
T u/s=-123.4 [F]   T d/s= -59.0 [F]   Pin =4428.0 [psia]   Pout = 3400.0 [psia]
T in =-127.6 [F]   Tout = -72.3 [F]   H in= 246.6   H out = 301.5 [Btu/lb]

Vol.Flow = 5.31 [GPM]   Mass Flow = .2628[lb/s]   Mass Flux = 62.79[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	36.6	30.9	27.6	-125.5	-121.0	3843.9	7.169	.48237E-01
.97	13.3	46.1	40.2	36.9	-120.0	-115.4	3797.7	7.299	.47939E-01
1.91	26.2	70.4	64.1	60.6	-110.2	-105.5	3712.8	7.632	.45943E-01
4.16	57.0	62.3	56.2	52.7	-98.0	-92.9	3601.5	7.522	.51678E-01
5.02	68.8	109.0	102.1	98.3	-88.1	-82.8	3508.7	8.158	.45066E-01
6.10	83.6	120.7	113.6	109.7	-80.5	-74.9	3436.7	8.319	.45068E-01
6.84	93.7	131.4	124.1	120.1	-74.5	-68.8	3379.4	8.464	.44803E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.51	11.34	.92	1805.	81.	1.57	.07	1.64	.00
.97	.885	.52	11.35	.94	1804.	82.	1.60	.07	1.67	.00
1.91	1.595	.54	11.36	.98	1800.	86.	1.67	.08	1.75	.00
4.16	1.555	.54	11.36	.96	1801.	85.	1.65	.08	1.73	.00
5.02	.970	.58	11.39	1.05	1794.	92.	1.78	.09	1.87	.00
6.10	.910	.60	11.39	1.07	1793.	94.	1.81	.09	1.91	.00
6.84	.550	.61	11.40	1.09	1791.	95.	1.84	.10	1.94	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	412.7	.1694E+07	1.290	.686	1.75	.2028E+04	.9278E-03
.97	418.6	.1759E+07	1.270	.684	1.76	.2051E+04	.9182E-03
1.91	429.7	.1905E+07	1.220	.672	1.78	.2026E+04	.8716E-03
4.16	445.3	.1897E+07	1.321	.706	1.78	.2419E+04	.9654E-03
5.02	459.5	.2008E+07	1.323	.666	1.91	.2201E+04	.8290E-03
6.10	471.5	.2101E+07	1.329	.666	1.87	.2285E+04	.8182E-03
6.84	481.7	.2179E+07	1.337	.664	1.84	.2342E+04	.8040E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-125.5	3843.9	248.322	.3246E-04	.20835E-04	.8280	21.908
.97	-120.0	3797.7	252.879	.3127E-04	.20474E-04	.8315	21.603
1.91	-110.2	3712.8	261.021	.2887E-04	.19868E-04	.8395	21.044
4.16	-98.0	3601.5	271.473	.2899E-04	.18711E-04	.8525	20.305
5.02	-88.1	3508.7	280.074	.2740E-04	.17935E-04	.8658	19.679
6.10	-80.5	3436.7	286.849	.2618E-04	.17281E-04	.8772	19.177
6.84	-74.5	3379.4	292.203	.2524E-04	.16760E-04	.8875	18.772

CALC. CHECK: Wattmeter Qe =13.18[kw]   Sensible Qs =15.23[kw]   Qerr = 15.57%
Meas. V = 6.918 [volts]   Calc. V = 6.984 [volts]   Verr = .957%
Meas. I =1904.4 [amps]   Calc. I =1886.4 [amps]   Ierr = .95%
Meas. Tout = -64.2 [F]   Calc. Tout = -72.3 [F]   Terr = 8.1 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-1B   TIME = 10:46:34   TUBE L = 7.00 [in]   # OF TC = 7

Qabse =19.73 [KWe]   I =2077.9 [amps]   V = 9.492 [volts]   R = 4.57 [mOhms]
T u/s=-117.5 [F]   T d/s= -22.2 [F]   Pin =4395.0 [psia]   Pout = 3432.0 [psia]
T in =-121.2 [F]   Tout = -33.0 [F]   H in= 252.1   H out = 334.2 [Btu/lb]

Vol Flow = 4.96 [GPM]   Mass Flow = .2423[lb/s]   Mass Flux = 57.89[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	124.0	115.4	110.7	-118.0	-114.1	3890.4	10.062	.44754E-01
.97	13.3	150.8	141.7	136.8	-109.5	-105.4	3847.2	10.498	.43351E-01
1.91	26.2	198.9	188.8	183.5	-94.2	-89.9	3766.3	11.279	.41261E-01
4.16	57.0	185.4	175.6	170.4	-75.0	-70.2	3658.3	11.062	.45979E-01
5.02	68.8	280.3	268.5	262.5	-59.3	-54.1	3566.1	12.585	.39754E-01
6.10	83.6	318.1	305.6	299.2	-46.6	-41.0	3491.5	13.184	.38750E-01
6.84	93.7	348.8	335.6	329.0	-36.7	-30.7	3431.3	13.670	.37999E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.59	11.40	1.17	1975.	103.	2.19	.11	2.31	.00
.97	.885	.62	11.41	1.22	1971.	107.	2.28	.12	2.41	.00
1.91	1.595	.67	11.44	1.31	1963.	115.	2.44	.14	2.59	.00
4.16	1.555	.66	11.43	1.29	1965.	113.	2.40	.14	2.54	.00
5.02	.970	.75	11.49	1.47	1950.	128.	2.71	.18	2.89	.00
6.10	.910	.79	11.51	1.54	1945.	133.	2.83	.19	3.02	.00
6.84	.530	.82	11.53	1.59	1940.	138.	2.93	.21	3.13	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/Twall	MUbulk/MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	386.4	.1628E+07	1.255	.599	2.09	.1905E+04	.9324E-03
.97	394.6	.1619E+07	1.332	.587	2.16	.1936E+04	.8979E-03
1.91	410.9	.1737E+07	1.307	.568	2.05	.1912E+04	.8424E-03
4.16	435.1	.1908E+07	1.315	.611	1.89	.2298E+04	.9159E-03
5.02	458.3	.2070E+07	1.327	.555	1.78	.2126E+04	.7741E-03
6.10	479.4	.2214E+07	1.334	.544	1.68	.2190E+04	.7419E-03
6.84	497.9	.2336E+07	1.336	.536	1.59	.2244E+04	.7189E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-118.0	3890.4	254.746	.3115E-04	.20581E-04	.8290	21.578
.97	-109.5	3847.2	261.803	.3132E-04	.19618E-04	.8339	21.128
1.91	-94.2	3766.3	274.679	.2919E-04	.18904E-04	.8460	20.287
4.16	-75.0	3658.3	291.379	.2657E-04	.17525E-04	.8671	19.159
5.02	-59.3	3566.1	305.335	.2450E-04	.16379E-04	.8870	18.192
6.10	-46.6	3491.5	316.781	.2291E-04	.15500E-04	.9022	17.389
6.84	-36.7	3431.3	325.879	.2171E-04	.14834E-04	.9130	16.745

CALC. CHECK: Wattmeter Qe =19.73[kw]   Sensible Qs =20.98[kw]   Qerr = 6.37%
Meas. V = 9.379 [volts]   Calc. V = 9.492 [volts]   Verr = 1.212%
Meas. I =2103.2 [amps]   Calc. I =2077.9 [amps]   Ierr = 1.20%
Meas Tout = -27.6 [F]   Calc. Tout = -33.0 [F]   Terr = 5.4 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-1C TIME = 10:42:47 TUBE L = 7.02 [in] # OF TC = 7

Qabse = 5.25 [KWe] I =1217.4 [amps] V = 4.312 [volts] R = 3.54 [mOhms]
T u/s= -65.0 [F] T d/s= -26.4 [F] Pin =4509.0 [psia] Pout = 3937.0 [psia]
T in = -67.2 [F] Tout = -33.3 [F] H in= 298.1 H out = 330.9 [Btu/lb]

Vol Flow = 3.92 [GPM] Mass Flow = .1714[lb/s] Mass Flux = 40.95[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	23.4	21.0	19.6	-65.9	-63.5	4225.1	2.980	.35846E-01
.97	13.3	27.2	24.8	23.4	-62.5	-60.0	4202.5	3.003	.35999E-01
1.91	26.2	37.6	35.1	33.7	-56.5	-54.0	4161.9	3.064	.34935E-01
4.16	57.0	37.1	34.6	33.2	-49.0	-46.4	4109.4	3.061	.38477E-01
5.02	68.8	54.1	51.5	50.0	-42.9	-40.2	4066.5	3.161	.35041E-01
6.10	83.6	57.9	55.3	53.8	-38.3	-35.5	4033.9	3.184	.35659E-01
6.84	93.7	65.2	62.5	61.0	-34.7	-31.9	4008.3	3.227	.34751E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.51	11.34	.59	1165.	52.	.65	.03	.68	.00
.97	.885	.51	11.34	.60	1165.	53.	.66	.03	.69	.00
1.91	1.595	.52	11.34	.61	1164.	54.	.67	.03	.70	.00
4.16	1.555	.52	11.34	.61	1164.	54.	.67	.03	.70	.00
02	.970	.54	11.35	.63	1162.	55.	.69	.03	.72	.00
.10	.910	.54	11.36	.63	1162.	56.	.70	.03	.73	.00
6.84	.550	.55	11.36	.64	1161.	56.	.71	.03	.74	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	304.4	.1317E+07	1.271	.822	1.38	.1747E+04	.1044E-02
.97	307.4	.1334E+07	1.274	.822	1.39	.1776E+04	.1045E-02
1.91	312.9	.1363E+07	1.279	.817	1.41	.1755E+04	.1007E-02
4.16	320.3	.1401E+07	1.282	.833	1.37	.1975E+04	.1100E-02
5.02	326.6	.1433E+07	1.2[illegible]	.818	1.42	.1827E+04	.9945E-03
6.10	331.6	.1457E+07	1.287	.821	1.41	.1889E+04	.1007E-02
6.84	335.7	.1477E+07	1.281	.816	1.43	.1851E+04	.9781E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-65.9	4225.1	299.207	.2724E-04	.17969E-04	.8384	19.372
.97	-62.5	4202.5	302.120	.2690E-04	.17757E-04	.8411	19.184
1.91	-56.5	4161.9	307.160	.2633E-04	.17436E-04	.8470	18.847
4.16	-49.0	4109.4	313.611	.2561E-04	.17068E-04	.8544	18.411
5.02	-42.9	4066.5	318.847	.2504E-04	.16801E-04	.8604	18.054
10	-38.3	4033.9	322.834	.2462E-04	.16535E-04	.8644	17.782
84	-34.7	4008.3	325.959	.2429E-04	.16447E-04	.8676	17.567

CALC. CHECK: Wattmeter Qe = 5.25[kw] Sensible Qs = 5.93[kw] Qerr = 12.96%
Meas. V = 4.142 [volts] Calc. V = 4.312 [volts] Verr = 4.098%
Meas. I =1267.4 [amps] Calc. I =1217.4 [amps] Ierr = 3.94%
Meas. Tout = -29.0 [F] Calc. Tout = -33.3 [F] Terr = 4.3 [F]

ORIGINAL [illegible] OF POOR [illegible]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-2A   TIME = 11:24:51   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =13.03 [KWe]   I =1896.1 [amps]   V = 6.869 [volts]   R = 3.62 [mOhms]
T u/s=-125.1 [F]   T d/s= -65.3 [F]   Pin =4398.0 [psia]   Pout = 3244.0 [psia]
T in =-129.2 [F]   Tout = -73.5 [F]   H in= 245.3   H out = 296.0 [Btu/lb]

Vol Flow = 5.21 [GPM]   Mass Flow = .2585[lb/s]   Mass Flux = 61.76[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	26.8	21.2	17.9	-127.0	-122.7	3833.9	7.103	.50506E-01
.97	13.3	36.1	30.3	27.0	-121.4	-117.0	3789.0	7.232	.50207E-01
1.91	26.2	58.9	52.8	49.3	-111.6	-107.1	3706.9	7.548	.48269E-01
4.16	57.0	51.0	45.0	41.6	-99.3	-94.4	3599.2	7.440	.54720E-01
5.02	68.8	95.8	89.0	85.3	-89.4	-84.2	3509.6	8.058	.47531E-01
6.10	83.6	105.9	99.0	95.1	-81.7	-76.3	3440.1	8.198	.47807E-01
6.84	93.7	118.0	110.9	106.9	-75.7	-70.2	3384.8	8.364	.47215E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.50	11.34	.91	1816.	80.	1.56	.07	1.63	.00
.97	.885	.51	11.34	.92	1815.	81.	1.59	.07	1.66	.00
1.91	1.595	.53	11.36	.96	1811.	85.	1.65	.08	1.73	.00
4.16	1.555	.52	11.35	.95	1812.	84.	1.63	.08	1.71	.00
02	.970	.57	11.38	1.03	1806.	90.	1.76	.09	1.85	.00
.10	.910	.58	11.39	1.05	1804.	92.	1.79	.09	1.88	.00
6.84	.550	.59	11.39	1.07	1802.	94.	1.82	.09	1.92	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	404.8	.1655E+07	1.296	.697	1.70	.2118E+04	.9875E-03
.97	410.5	.1715E+07	1.277	.695	1.72	.2143E+04	.9780E-03
1.91	421.3	.1852E+07	1.231	.684	1.74	.2124E+04	.9314E-03
4.16	436.6	.1856E+07	1.322	.719	1.73	.2553E+04	.1040E-02
5.02	450.4	.1964E+07	1.322	.680	1.87	.2310E+04	.8900E-03
6.10	462.1	.2054E+07	1.329	.681	1.84	.2414E+04	.8840E-03
6.84	471.9	.2130E+07	1.336	.678	1.82	.2457E+04	.8633E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-127.0	3833.9	247.026	.3269E-04	.20894E-04	.8281	21.974
.97	-121.4	3789.0	251.620	.3154E-04	.20527E-04	.8311	21.668
1.91	-111.6	3706.9	259.809	.2921E-04	.19912E-04	.8391	21.110
4.16	-99.3	3599.2	270.318	.2915E-04	.18779E-04	.8518	20.372
5.02	-89.4	3509.6	278.961	.2756E-04	.18022E-04	.8646	19.748
10	-81.7	3440.1	285.756	.2634E-04	.17347E-04	.8755	19.249
84	-75.7	3384.8	291.121	.2540E-04	.16831E-04	.8854	18.847

CALC. CHECK: Wattmeter Qe =13.03[kw]   Sensible Qs =13.84[kw]   Qerr = 6.25%
Meas. V = 6.783 [volts]   Calc. V = 6.869 [volts]   Verr = 1.274%
Meas. I =1920.2 [amps]   Calc. I =1896.1 [amps]   Ierr = 1.26%
Meas. Tout = -70.3 [F]   Calc. Tout = -73.5 [F]   Terr = 3.2 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-2B TIME = 11:25:54 TUBE L = 7.02 [in] # OF TC = 7

Qabse =17.48 [KWe] I =2054.7 [amps] V = 8.505 [volts] R = 4.14 [mOhms]
T u/s=-121.8 [F] T d/s= -42.0 [F] Pin =4378.0 [psia] Pout = 3272.0 [psia]
T in =-125.6 [F] Tout = -49.2 [F] H in= 248.3 H out = 316.7 [Btu/lb]

Vol Flow = 5.05 [GPM] Mass Flow = .2489[lb/s] Mass Flux = 59.48[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	83.7	76.1	71.8	-122.7	-118.7	3850.1	9.202	.48296E-01
.97	13.3	101.1	93.2	88.7	-115.2	-111.1	3806.2	9.481	.47441E-01
1.91	26.2	138.0	129.3	124.6	-101.9	-97.4	3724.4	10.071	.45354E-01
4.16	57.0	123.5	115.1	110.5	-85.1	-80.3	3615.9	9.842	.51581E-01
5.02	68.8	195.5	185.7	180.5	-71.5	-66.3	3524.3	10.986	.44509E-01
6.10	83.6	216.8	206.6	201.2	-60.8	-55.3	3451.6	11.321	.44143E-01
6.84	93.7	236.2	225.6	220.0	-52.4	-46.6	3392.7	11.626	.43607E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.55	11.37	1.08	1959.	95.	2.01	.10	2.11	.00
.97	.885	.57	11.38	1.12	1957.	98.	2.07	.10	2.17	.00
1.91	1.595	.61	11.41	1.19	1951.	104.	2.19	.12	2.31	.00
4.16	1.555	.59	11.40	1.16	1953.	102.	2.15	.11	2.26	.00
02	.970	.67	11.44	1.29	1942.	113.	2.38	.14	2.52	.00
.10	.910	.69	11.45	1.33	1938.	116.	2.45	.15	2.60	.00
6.84	.550	.71	11.46	1.37	1935.	119.	2.51	.15	2.67	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	393.3	.1630E+07	1.279	.634	1.99	.2043E+04	.9796E-03
.97	400.6	.1718E+07	1.245	.628	1.98	.2049E+04	.9575E-03
1.91	415.1	.1740E+07	1.318	.613	2.09	.2074E+04	.9040E-03
4.16	436.0	.1894E+07	1.316	.657	1.92	.2508E+04	.1006E-02
5.02	455.6	.2037E+07	1.326	.607	1.85	.2298E+04	.8508E-03
6.10	473.0	.2162E+07	1.336	.604	1.78	.2396E+04	.8298E-03
6.84	488.0	.2268E+07	1.344	.599	1.70	.2466E+04	.8090E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-122.7	3850.1	250.640	.3197E-04	.20712E-04	.8289	21.779
.97	-115.2	3806.2	256.862	.3032E-04	.20286E-04	.8330	21.378
1.91	-101.9	3724.4	268.127	.2995E-04	.19159E-04	.8434	20.633
4.16	-85.1	3615.9	282.614	.2751E-04	.18015E-04	.8616	19.643
5.02	-71.5	3524.3	294.617	.2558E-04	.16964E-04	.8795	18.799
10	-60.8	3451.6	304.274	.2410E-04	.16136E-04	.8943	18.109
84	-52.4	3392.7	311.955	.2298E-04	.15492E-04	.9063	17.552

CALC. CHECK: Wattmeter Qe =17.48[kw] Sensible Qs =17.97[kw] Qerr = 2.82%
Meas. V = 8.452 [volts] Calc. V = 8.505 [volts] Verr = .623%
Meas. I =2067.5 [amps] Calc. I =2054.7 [amps] Ierr = .62%
Meas. Tout = -47.2 [F] Calc. Tout = -49.2 [F] Terr = 2.0 [F]

ORIGINAL PAGE IS OF POOR QUALITY

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-3A TIME = 1:16:40 TUBE L = 7.02 [in] # OF TC = 7

Qabs = 16.75 [KWe] I = 2029.1 [amps] V = 8.255 [volts] R = 4.07 [mOhms]
T u/s = -118.9 [F] T d/s = -42.2 [F] Pin = 4416.0 [psia] Pout = 3273.0 [psia]
T in = -123.0 [F] Tout = -52.0 [F] H in = 250.5 H out = 316.4 [Btu/lb]

Vol Flow = 5.23 [GPM] Mass Flow = .2565[lb/s] Mass Flux = 61.29[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	82.0	74.6	70.5	-120.3	-116.0	3853.6	8.958	.48055E-01
.97	13.3	95.1	87.5	83.2	-113.2	-108.8	3807.4	9.164	.47724E-01
1.91	26.2	128.2	119.9	115.4	-100.8	-96.0	3721.5	9.680	.45794E-01
4.16	57.0	114.1	106.1	101.7	-85.1	-80.0	3607.6	9.463	.52088E-01
5.02	68.8	178.1	168.8	163.9	-72.5	-67.0	3511.8	10.458	.45283E-01
6.10	83.6	197.6	188.0	182.9	-62.6	-56.8	3436.2	10.758	.44883E-01
6.84	93.7	213.5	203.5	198.3	-54.9	-48.8	3375.1	11.003	.44519E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.55	11.37	1.07	1935.	94.	1.96	.10	2.05	.00
.97	.885	.57	11.38	1.09	1933.	96.	2.00	.10	2.10	.00
1.91	1.595	.60	11.40	1.15	1928.	101.	2.11	.11	2.22	.00
4.16	1.555	.58	11.39	1.13	1930.	99.	2.06	.11	2.17	.00
02	.970	.65	11.43	1.25	1920.	109.	2.27	.13	2.40	.00
.10	.910	.67	11.44	1.28	1917.	112.	2.33	.14	2.47	.00
6.84	.550	.69	11.45	1.31	1914.	115.	2.38	.14	2.52	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	407.4	.1704E+07	1.269	.640	1.96	.2043E+04	.9453E-03
.97	414.8	.1798E+07	1.232	.638	1.93	.2069E+04	.9340E-03
1.91	429.0	.1802E+07	1.317	.624	2.06	.2100E+04	.8850E-03
4.16	449.5	.1954E+07	1.317	.667	1.89	.2537E+04	.9859E-03
5.02	468.6	.2095E+07	1.327	.621	1.86	.2335E+04	.8401E-03
6.10	485.3	.2217E+07	1.337	.618	1.78	.2428E+04	.8192E-03
6.84	499.7	.2320E+07	1.345	.615	1.72	.2501E+04	.8013E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-120.3	3853.6	252.710	.3152E-04	.20605E-04	.8294	21.663
.97	-113.2	3807.4	258.563	.2987E-04	.20208E-04	.8336	21.280
1.91	-100.8	3721.5	269.093	.2980E-04	.19101E-04	.8443	20.573
4.16	-85.1	3607.6	282.611	.2747E-04	.17987E-04	.8619	19.634
5.02	-72.5	3511.8	293.766	.2563E-04	.16988E-04	.8794	18.836
10	-62.6	3436.2	302.681	.2422E-04	.16193E-04	.8939	18.189
84	-54.9	3375.1	309.774	.2314E-04	.15592E-04	.9064	17.661

CALC. CHECK: Wattmeter Qe = 16.75[kw] Sensible Qs = 17.84[kw] Qerr = 6.49%
Meas. V = 8.176 [volts] Calc. V = 8.255 [volts] Verr = .970%
Meas. I = 2048.8 [amps] Calc. I = 2029.1 [amps] Ierr = .96%
Meas. Tout = -47.7 [F] Calc. Tout = -52.0 [F] Terr = 4.3 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-3B   TIME = 1:17:50   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =23.65 [KWe]   I =2165.6 [amps]   V = 10.920 [volts]   R = 5.04 [mOhms]
T u/s=-117.6 [F]   T d/s= -8.0 [F]   Pin =4364.0 [psia]   Pout = 3288.0 [psia]
T in =-121.3 [F]   Tout = -17.4 [F]   H in= 251.9   H out = 347.0 [Btu/lb]

Vol Flow = 4.98 [GPM]   Mass Flow = .2433[lb/s]   Mass Flux = 58.13[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	164.1	154.0	148.5	-117.6	-113.7	3854.5	11.589	.44186E-01
.97	13.3	199.5	188.6	182.8	-107.9	-103.7	3809.7	12.207	.42595E-01
1.91	26.2	260.7	248.5	242.1	-90.2	-85.8	3724.9	13.274	.40485E-01
4.16	57.0	248.4	236.4	230.2	-67.8	-62.8	3610.2	13.062	.44575E-01
5.02	68.8	370.4	355.7	348.4	-49.4	-43.8	3510.5	15.157	.38646E-01
6.10	83.6	433.5	417.4	409.5	-34.3	-28.2	3427.6	16.226	.37077E-01
6.84	93.7	501.1	483.6	474.9	-22.1	-15.4	3357.7	17.361	.35408E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.63	11.42	1.29	2052.	113.	2.52	.14	2.66	.00
.97	.885	.67	11.44	1.36	2046.	119.	2.65	.15	2.80	.00
1.91	1.595	.73	11.48	1.48	2036.	129.	2.86	.18	3.04	.00
4.16	1.555	.72	11.47	1.46	2038.	127.	2.82	.18	3.00	.00
02	.970	.84	11.55	1.69	2019.	147.	3.24	.24	3.48	.00
.10	.910	.90	11.58	1.81	2009.	157.	3.45	.27	3.72	.00
6.84	.550	.97	11.63	1.94	1999.	167.	3.67	.31	3.98	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	388.7	.1644E+07	1.255	.563	2.15	.1889E+04	.9155E-03
.97	398.2	.1643E+07	1.328	.548	2.16	.1912E+04	.8765E-03
1.91	417.8	.1783E+07	1.308	.527	2.03	.1908E+04	.8184E-03
4.16	447.3	.1990E+07	1.321	.568	1.84	.2300E+04	.8748E-03
5.02	476.4	.2189E+07	1.334	.508	1.66	.2160E+04	.7398E-03
6.10	504.1	.2371E+07	1.335	.490	1.51	.2209E+04	.6976E-03
6.84	530.3	.2531E+07	1.336	.468	1.38	.2229E+04	.6579E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-117.6	3854.5	254.946	.3098E-04	.20491E-04	.8303	21.535
.97	-107.9	3809.7	263.075	.3100E-04	.19516E-04	.8361	21.018
1.91	-90.2	3724.9	278.131	.2856E-04	.18586E-04	.8511	20.036
4.16	-67.8	3610.2	297.717	.2559E-04	.16980E-04	.8766	18.715
5.02	-49.4	3510.5	314.251	.2327E-04	.15676E-04	.8987	17.571
10	-34.3	3427.6	328.090	.2148E-04	.14705E-04	.9143	16.605
84	-22.1	3357.7	339.545	.2011E-04	.13916E-04	.9259	15.785

CALC. CHECK: Wattmeter Qe =23.65[kw]   Sensible Qs =24.42[kw]   Qerr = 3.26%
Meas. V = 4.961 [volts]   Calc. V =10.920 [volts]   Verr =******%
Meas. I =4767.3 [amps]   Calc. I =2165.6 [amps]   Ierr = 54.57%
Meas. Tout = -14.1 [F]   Calc. Tout = -17.4 [F]   Terr = 3.3 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-4A TIME = 2:07:25 TUBE L = 7.02 [in] # OF TC = 7

Qabse =19.77 [KWe] I =2151.7 [amps] V = 9.190 [volts] R = 4.27 [mOhms]
T u/s=-133.2 [F] T d/s= -45.2 [F] Pin =4347.0 [psia] Pout = 3157.0 [psia]
T in =-137.8 [F] Tout = -61.3 [F] H in= 237.7 H out = 314.2 [Btu/lb]

Vol Flow = 5.54 [GPM] Mass Flow = .2789[lb/s] Mass Flux = 66.65[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	96.3	87.8	83.0	-134.9	-130.0	3699.8	10.266	.48190E-01
.97	13.3	115.3	106.4	101.4	-127.5	-122.4	3646.6	10.599	.47350E-01
1.91	26.2	158.0	148.1	142.8	-114.0	-108.8	3547.6	11.344	.45094E-01
4.16	57.0	141.2	131.7	126.5	-97.2	-91.4	3415.9	11.053	.50722E-01
5.02	68.8	225.2	213.9	207.9	-83.7	-77.4	3304.0	12.505	.43819E-01
6.10	83.6	253.0	241.1	234.9	-73.0	-66.3	3214.2	12.979	.43087E-01
6.84	93.7	283.4	270.8	264.3	-64.5	-57.6	3141.0	13.497	.41931E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.56	11.38	1.15	2050.	101.	2.24	.11	2.35	.00
.97	.895	.58	11.39	1.19	2047.	105.	2.31	.12	2.43	.00
1.91	1.595	.63	11.42	1.28	2040.	112.	2.47	.14	2.60	.00
4.16	1.555	.61	11.41	1.24	2043.	109.	2.41	.13	2.53	.00
02	.970	.69	11.46	1.41	2029.	123.	2.70	.16	2.87	.00
.10	.910	.72	11.47	1.46	2024.	127.	2.80	.18	2.98	.00
6.84	.550	.75	11.49	1.52	2020.	132.	2.91	.19	3.10	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	431.2	.1734E+07	1.325	.599	2.21	.2000E+04	.8705E-03
.97	439.2	.1814E+07	1.307	.592	2.21	.2017E+04	.8509E-03
1.91	455.1	.1988E+07	1.263	.574	2.12	.2010E+04	.8007E-03
4.16	478.2	.2073E+07	1.332	.619	2.05	.2435E+04	.8817E-03
5.02	500.4	.2247E+07	1.342	.563	1.96	.2240E+04	.7424E-03
6.10	520.7	.2402E+07	1.358	.557	1.84	.2328E+04	.7133E-03
6.84	538.8	.2537E+07	1.372	.546	1.75	.2369E+04	.6807E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-134.9	3699.8	240.092	.3367E-04	.21110E-04	.8306	22.258
.97	-127.5	3646.6	246.303	.3219E-04	.20569E-04	.8349	21.850
1.91	-114.0	3547.6	257.599	.2936E-04	.19654E-04	.8451	21.089
4.16	-97.2	3415.9	272.125	.2817E-04	.18247E-04	.8632	20.070
5.02	-83.7	3304.0	284.286	.2598E-04	.17140E-04	.8856	19.178
10	-73.0	3214.2	294.159	.2430E-04	.16216E-04	.9064	18.431
84	-64.5	3141.0	302.091	.2301E-04	.15502E-04	.9242	17.811

CALC. CHECK: Wattmeter Qe =19.77[kw] Sensible Qs =22.50[kw] Qerr = 13.79%
Meas. V = 9.130 [volts] Calc. V = 9.190 [volts] Verr = .658%
Meas. I =2165.9 [amps] Calc. I =2151.7 [amps] Ierr = .66%
Meas. Tout = -51.5 [F] Calc. Tout = -61.3 [F] Terr = 9.8 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-4B.1 TIME = 2:08:29 TUBE L = 7.02 [in] # OF TC = 7

Qabse =25.52 [KWe] I =2218.1 [amps] V = 11.508 [volts] R = 5.19 [mOhms]
T u/s=-127.8 [F] T d/s= -15.6 [F] Pin =4157.0 [psia] Pout = 3094.0 [psia]
T in =-131.6 [F] Tout = -25.1 [F] H in= 242.8 H out = 342.0 [Btu/lb]

Vol Flow = 5.07 [GPM] Mass Flow = .2515[lb/s] Mass Flux = 60.08[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	160.0	149.6	143.9	-128.0	-123.9	3620.1	12.050	.45002E-01
.97	13.3	203.3	191.9	185.8	-118.2	-113.9	3573.0	12.846	.42862E-01
1.91	26.2	272.3	259.3	252.5	-100.2	-95.6	3483.5	14.099	.40507E-01
4.16	57.0	263.3	250.5	243.8	-77.4	-72.2	3361.5	13.937	.44098E-01
5.02	68.8	407.7	391.5	383.4	-58.7	-52.9	3254.1	16.523	.37868E-01
6.10	83.6	490.4	472.3	463.4	-43.1	-36.6	3162.6	17.979	.35955E-01
6.84	93.7	594.3	573.9	563.9	-30.2	-23.1	3084.1	19.786	.33707E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.63	11.42	1.31	2103.	115.	2.62	.14	2.76	.00
.97	.885	.67	11.44	1.40	2096.	122.	2.78	.16	2.95	.00
1.91	1.595	.74	11.49	1.54	2084.	134.	3.04	.20	3.23	.00
4.16	1.555	.73	11.48	1.52	2086.	132.	3.01	.19	3.20	.00
02	.970	.87	11.57	1.80	2062.	156.	3.52	.27	3.79	.00
.10	.910	.96	11.62	1.96	2049.	169.	3.81	.31	4.12	.00
6.84	.550	1.06	11.68	2.16	2033.	185.	4.16	.38	4.54	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	395.9	.1635E+07	1.309	.550	2.30	.1918E+04	.8961E-03
.97	405.7	.1738E+07	1.280	.529	2.18	.1885E+04	.8473E-03
1.91	426.1	.1826E+07	1.330	.505	2.11	.1910E+04	.7864E-03
4.16	457.5	.2064E+07	1.337	.544	1.89	.2286E+04	.8280E-03
5.02	489.9	.2294E+07	1.361	.476	1.65	.2145E+04	.6871E-03
6.10	522.4	.2509E+07	1.377	.452	1.47	.2195E+04	.6352E-03
6.84	553.8	.2703E+07	1.386	.420	1.32	.2192E+04	.5849E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-128.0	3620.1	245.824	.3219E-04	.20549E-04	.8359	21.855
.97	-118.2	3573.0	254.084	.3028E-04	.19919E-04	.8420	21.323
1.91	-100.2	3483.5	269.510	.2882E-04	.18580E-04	.8574	20.302
4.16	-77.4	3361.5	289.673	.2550E-04	.16900E-04	.8864	18.910
5.02	-58.7	3254.1	306.942	.2294E-04	.15463E-04	.9174	17.660
10	-43.1	3162.6	321.675	.2097E-04	.14352E-04	.9421	16.562
84	-30.2	3084.1	334.054	.1947E-04	.13473E-04	.9592	15.622

CALC. CHECK: Wattmeter Qe =25.52[kw] Sensible Qs =26.31[kw] Qerr = 3.09%
Meas. V =11.225 [volts] Calc. V =11.508 [volts] Verr = 2.518%
Meas. I =2273.9 [amps] Calc. I =2218.1 [amps] Ierr = 2.46%
Meas. Tout = -22.0 [F] Calc. Tout = -25.1 [F] Terr = 3.2 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-4B.2   TIME = 2:08:35   TUBE L = 7.02 [in]   # OF TC = 7

(Qabse =25.35 [KWe]   I =2208.1 [amps]   V = 11.481 [volts]   R = 5.20 [:Ohms]
T u/s=-126.7 [F]   T d/s= -13.2 [F]   Pin =4126.0 [psia]   Pout = 3019.0 [psia]
T in =-130.7 [F]   Tout = -27.1 [F]   H in= 243.5   H out = 344.6 [Btu/lb]

Vol Flow = 5.17 [GPM]   Mass Flow = .2552[lb/s]   Mass Flux = 60.96[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	164.3	153.8	148.2	-127.1	-122.8	3571.6	12.025	.44371E-01
.97	13.3	205.6	194.2	188.1	-117.5	-113.1	3523.3	12.778	.42417E-01
1.91	26.2	275.1	262.1	255.4	-100.0	-95.2	3431.2	14.029	.40022E-01
4.16	57.0	265.4	252.6	246.0	-77.8	-72.4	3305.6	13.856	.43514E-01
5.02	68.8	408.1	392.1	384.0	-59.5	-53.6	3195.0	16.389	.37450E-01
6.10	83.6	488.8	470.9	462.1	-44.4	-37.8	3100.9	17.798	.35604E-01
6.84	93.7	591.8	571.6	561.7	-32.0	-24.7	3020.3	19.574	.33380E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS [Btu/s-in]
.14	.555	.63	11.42	1.32	2093.	115.	2.61	.14	2.76	.00
.97	.885	.67	11.45	1.40	2086.	122.	2.77	.16	2.93	.00
1.91	1.595	.74	11.49	1.54	2074.	134.	3.02	.20	3.22	.00
4.16	1.555	.73	11.48	1.52	2076.	132.	2.99	.19	3.18	.00
02	.970	.87	11.57	1.80	2053.	155.	3.49	.26	3.76	.00
.10	.910	.96	11.62	1.95	2040.	168.	3.77	.31	4.08	.00
6.84	.550	1.06	11.68	2.15	2024.	184.	4.12	.37	4.49	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	403.2	.1674E+07	1.310	.547	2.29	.1905E+04	.8686E-03
.97	413.2	.1780E+07	1.281	.528	2.18	.1879E+04	.8240E-03
1.91	433.8	.1868E+07	1.334	.503	2.11	.1901E+04	.7631E-03
4.16	465.8	.2112E+07	1.345	.541	1.89	.2274E+04	.8007E-03
5.02	498.6	.2348E+07	1.368	.474	1.64	.2137E+04	.6651E-03
6.10	531.4	.2568E+07	1.386	.451	1.46	.2189E+04	.6152E-03
6.84	563.2	.2765E+07	1.397	.419	1.31	.2187E+04	.5663E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-127.1	3571.6	246.493	.3190E-04	.20407E-04	.8380	21.773
.97	-117.5	3523.3	254.605	.3000E-04	.19778E-04	.8444	21.245
1.91	-100.0	3431.2	269.713	.2859E-04	.18444E-04	.8603	20.235
4.16	-77.8	3305.6	289.524	.2528E-04	.16760E-04	.8914	18.847
5.02	-59.5	3195.0	306.408	.2274E-04	.15354E-04	.9237	17.608
10	-44.4	3100.9	320.786	.2080E-04	.14249E-04	.9493	16.519
84	-32.0	3020.3	332.834	.1931E-04	.13369E-04	.9669	15.588

CALC. CHECK: Wattmeter Qe =25.35[kw]   Sensible Qs =27.22[kw]   Qerr = 7.36%
Meas. V =11.225 [volts]   Calc. V =11.481 [volts]   Verr = 2.278%
Meas. I =2258.4 [amps]   Calc. I =2208.1 [amps]   Ierr = 2.23%
Meas. Tout = -19.7 [F]   Calc. Tout = -27.1 [F]   Terr = 7.4 [F]

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METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-21-4C   TIME = 2:09:15   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =30.33 [kWe]   I =2238.9 [amps]   V = 13.544 [volts]   R = 6.05 [mOhms]
T u/s=-123.2 [F]   T d/s= 11.2 [F]   Pin =3995.0 [psia]   Pout = 2855.0 [psia]
T in =-126.8 [F]   Tout = .5 [F]   H in= 246.6   H out = 368.5 [Btu/lb]

Vol Flow = 4.96 [GPM]   Mass Flow = .2422[lb/s]   Mass Flux = 57.86[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	213.8	201.9	195.6	-122.7	-118.8	3488.4	13.270	.42205E-01
.97	13.3	279.6	266.2	259.2	-111.5	-107.5	3442.3	14.485	.39504E-01
1.91	26.2	380.7	364.9	356.9	-90.6	-86.0	3352.3	16.329	.36863E-01
4.16	57.0	420.6	403.9	395.5	-63.2	-57.9	3225.3	17.049	.37601E-01
5.02	68.8	634.6	612.9	602.3	-39.7	-33.6	3107.6	20.846	.32783E-01
6.10	83.6	700.4	677.3	666.0	-20.3	-13.0	3001.8	21.991	.32367E-01
6.84	93.7	727.5	703.8	692.2	-5.1	3.3	2909.7	22.457	.32597E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	MONEL	VOLTAGE [volt/in]	CURRENT CU [amps]	MONEL	HEAT GEN. CU [Btu/s-in]	MONEL	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.68	11.45	1.43	2114.	125.	2.87	.17	3.04	.00
.97	.885	.74	11.49	1.57	2103.	136.	3.12	.20	3.32	.00
1.91	1.595	.85	11.55	1.76	2086.	153.	3.49	.26	3.74	.00
4.16	1.555	.89	11.58	1.84	2080.	159.	3.63	.28	3.91	.00
02	.970	1.10	11.71	2.25	2046.	192.	4.37	.41	4.78	.00
.10	.910	1.17	11.75	2.38	2037.	202.	4.59	.46	5.04	.00
6.84	.550	1.19	11.76	2.43	2033.	206.	4.68	.47	5.15	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	387.8	.1642E+07	1.302	.514	2.26	.1849E+04	.8649E-03
.97	399.4	.1777E+07	1.259	.485	2.10	.1795E+04	.8018E-03
1.91	424.5	.1874E+07	1.336	.452	1.95	.1825E+04	.7290E-03
4.16	466.1	.2178E+07	1.363	.464	1.67	.2105E+04	.7093E-03
5.02	512.8	.2484E+07	1.385	.396	1.36	.2049E+04	.5957E-03
6.10	561.8	.2770E+07	1.399	.391	1.20	.2222E+04	.5736E-03
6.84	608.5	.3012E+07	1.399	.395	1.09	.2405E+04	.5706E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-122.7	3488.4	250.095	.3087E-04	.19993E-04	.8433	21.484
.97	-111.5	3442.3	259.693	.2852E-04	.19284E-04	.8514	20.860
1.91	-90.6	3352.3	278.051	.2705E-04	.17692E-04	.8739	19.630
4.16	-63.2	3225.3	302.976	.2328E-04	.15648E-04	.9162	17.876
5.02	-39.7	3107.6	325.103	.2040E-04	.14015E-04	.9511	16.247
.10	-20.3	3001.8	343.955	.1830E-04	.12767E-04	.9759	14.831
.84	-5.1	2909.7	359.444	.1683E-04	.11875E-04	.9873	13.693

CALC. CHECK: Wattmeter Qe =30.33[kw] Sensible Qe =31.14[kw] Qerr = 2.70%
Meas. V =11.472 [volts] Calc. V =13.544 [volts] Verr =18.067%
Meas. I =2643.5 [amps] Calc. I =2238.9 [amps] Ierr = 15.30% out of range
Meas. Tout = 3.7 [F] Calc. Tout = .5 [F] Terr = 3.2 [F]

METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-24-2A   TIME = 11:00:48   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =35.67 [KWe]   I =2442.4 [amps]   V = 14.607 [volts]   R = 5.98 [mOhms]
T u/s=-120.3 [F]   T d/s= 6.7 [F]   Pin =4380.0 [psia]   Pout = 2477.0 [psia]
T in =-125.5 [F]   Tout = -.4 [F]   H in= 248.0   H out = 362.0 [Btu/lb]

Vol Flow = 5.87 [GPM]   Mass Flow = .2881[lb/s]   Mass Flux = 68.84[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	275.6	260.1	251.9	-121.0	-115.5	3670.9	16.970	.46181E-01
.97	13.3	356.0	338.2	329.2	-108.8	-102.9	3606.2	18.701	.43279E-01
1.91	26.2	429.5	409.7	399.8	-86.4	-80.0	3478.5	20.265	.42241E-01
4.16	57.0	492.8	471.3	460.6	-57.5	-49.9	3296.0	21.600	.42309E-01
5.02	68.8	551.4	528.3	516.9	-34.3	-25.3	3126.9	22.825	.42099E-01
6.10	83.6	543.8	520.9	509.6	-17.4	-6.9	2979.1	22.667	.43880E-01
6.84	93.7	572.0	548.4	536.7	-5.0	7.1	2851.6	23.254	.43904E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.73	11.49	1.68	2296.	146.	3.66	.23	3.89	.00
.97	.885	.81	11.54	1.85	2282.	161.	4.01	.28	4.29	.00
1.91	1.595	.88	11.58	2.01	2269.	173.	4.32	.33	4.65	.00
4.16	1.555	.95	11.62	2.14	2258.	184.	4.58	.37	4.95	.00
.02	.970	1.01	11.66	2.26	2248.	194.	4.82	.42	5.23	.00
.10	.910	1.00	11.65	2.25	2250.	193.	4.79	.41	5.20	.00
6.84	.550	1.03	11.67	2.30	2245.	197.	4.90	.43	5.33	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	460.0	.1938E+07	1.284	.476	2.23	.1996E+04	.8020E-03
.97	475.0	.1983E+07	1.341	.445	2.20	.1977E+04	.7438E-03
1.91	506.9	.2227E+07	1.325	.434	1.90	.2084E+04	.7062E-03
4.16	561.0	.2618E+07	1.356	.437	1.60	.2389E+04	.6728E-03
5.02	621.0	.3012E+07	1.381	.436	1.38	.2672E+04	.6425E-03
6.10	678.5	.3352E+07	1.403	.456	1.25	.3056E+04	.6497E-03
6.84	732.5	.3640E+07	1.408	.457	1.15	.3287E+04	.6412E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-121.0	3670.9	251.799	.3112E-04	.20267E-04	.8364	21.552
.97	-108.8	3606.2	262.157	.3041E-04	.19173E-04	.8453	20.872
1.91	-86.4	3478.5	281.551	.2708E-04	.17755E-04	.8689	19.556
4.16	-57.5	3296.0	307.788	.2303E-04	.15513E-04	.9135	17.671
5.02	-34.3	3126.9	330.009	.2002E-04	.13800E-04	.9519	15.964
6.10	-17.4	2979.1	346.851	.1799E-04	.12576E-04	.9811	14.610
84	-5.0	2851.6	360.397	.1657E-04	.11701E-04	.9946	13.533

CALC. CHECK: Wattmeter Qe =35.67[kw]   Sensible Qs =34.65[kw]   Qerr = 2.86%
Meas. V =14.659 [volts]   Calc. V =14.607 [volts]   Verr = .353%
Meas. I =2433.7 [amps]   Calc. I =2442.4 [amps]   Ierr = .36%
Meas. Tout = -4.1 [F]   Calc. Tout = -.4 [F]   Terr = 3.7 [F]

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METHANE HEAT TRANSFER INVESTIGATION

CASE = 5-24-2B   TIME = 11:01:28   TUBE L = 7.02 [in]   # OF TC = 7

Qabse =39.92 [KWe]   I =2473.8 [amps]   V = 16.139 [volts]   R = 6.52 [mOhms]
T u/s=-116.5 [F]   T d/s= 24.1 [F]   Pin =4375.0 [psia]   Pout = 2421.0 [psia]
T in =-121.4 [F]   Tout = 22.8 [F]   H in= 251.6   H out = 377.3 [Btu/lb]

Vol Flow = 5.71 [GPM]   Mass Flow = .2780[lb/s]   Mass Flux = 66.43[lb/s-in2]

WALL LOC. X[in]	X/ID	OUTER WALL T[F]	INTERF WALL T[F]	INNER WALL T[F]	FLUID BULK T[F]	ADIAB. WALL T T[F]	FLUID PRESS [psia]	HEAT FLUX [Btu/s-in**2]	h TRANSFER COEFFICIENT
.14	1.9	324.2	306.9	298.0	-116.4	-111.2	3708.6	18.453	.45092E-01
.97	13.3	453.3	432.4	422.0	-102.3	-96.7	3644.9	21.271	.41015E-01
1.91	26.2	549.1	525.6	513.9	-75.8	-69.5	3516.3	23.329	.39985E-01
4.16	57.0	577.8	553.5	541.5	-42.2	-34.5	3328.8	23.939	.41562E-01
5.02	68.8	637.0	611.1	598.3	-15.8	-6.3	3151.0	25.193	.41669E-01
6.10	83.6	633.6	607.8	595.1	3.3	14.9	2990.7	25.121	.43301E-01
6.84	93.7	666.6	639.9	626.7	17.5	31.5	2848.9	25.816	.43372E-01

WALL LOC. X[in]	TUBE SEG DL [in]	RESISTANCE CU [mOhms/in]	RESISTANCE MONEL [mOhms/in]	VOLTAGE [volt/in]	CURRENT CU [amps]	CURRENT MONEL [amps]	HEAT GEN. CU [Btu/s-in]	HEAT GEN. MONEL [Btu/s-in]	TOTAL Q GEN [Btu/s-in]	HEAT LOSS
.14	.555	.78	11.52	1.81	2317.	157.	3.96	.27	4.23	.00
.97	.885	.91	11.60	2.08	2294.	179.	4.52	.35	4.88	.00
1.91	1.595	1.00	11.65	2.28	2278.	196.	4.93	.42	5.35	.00
4.16	1.555	1.03	11.67	2.34	2273.	201.	5.04	.45	5.49	.00
02	.970	1.09	11.71	2.46	2263.	210.	5.29	.49	5.49	.00
.10	.910	1.09	11.71	2.46	2264.	210.	5.27	.49	5.78	.00.
6.84	.550	1.12	11.73	2.53	2258.	215.	5.41	.52	5.76	.00

WALL LOC. X[in]	FLUID VEL. [ft/s]	REYNOLDS NUMBER	PRANDTL NUMBER	Tbulk/ Twall	MUbulk/ MUwall	NUSSELT NUMBER	STANTON NUMBER
.14	448.0	.1920E+07	1.260	.453	2.17	.1963E+04	.8113E-03
.97	465.0	.1960E+07	1.324	.406	2.04	.1890E+04	.7286E-03
1.91	502.8	.2236E+07	1.327	.394	1.75	.2039E+04	.6872E-03
4.16	567.4	.2679E+07	1.353	.417	1.46	.2461E+04	.6790E-03
5.02	640.5	.3117E+07	1.372	.420	1.24	.2802E+04	.6549E-03
6.10	712.4	.3490E+07	1.372	.439	1.12	.3213E+04	.6709E-03
6.84	781.1	.3800E+07	1.345	.439	1.02	.3467E+04	.6782E-03

WALL LOC. X[in]	FLUID TEMP. [F]	FLUID PRESS [psia]	ENTHALPY [Btu/lb]	DYNAMIC VISCOSITY [lb/ft-s]	THERMAL CONDUCTIVITY [Btu/s-ft]	SPECIFIC HEAT [Btu/lb-R]	DENSITY [lb/ft3]
.14	-116.4	3708.6	255.791	.3030E-04	.20121E-04	.8367	21.351
.97	-102.3	3644.9	267.797	.2969E-04	.19011E-04	.8474	20.572
1.91	-75.8	3516.3	290.821	.2603E-04	.17177E-04	.8758	19.027
4.16	-42.2	3328.8	321.460	.2172E-04	.14792E-04	.9215	16.859
5.02	-15.8	3151.0	346.928	.1867E-04	.13029E-04	.9578	14.935
6.10	3.3	2990.7	366.201	.1667E-04	.11804E-04	.9716	13.427
84	17.5	2848.9	382.156	.1532E-04	.10957E-04	.9626	12.246

CALC. CHECK: Wattmeter Qe =39.92[kw]   Sensible Qs =36.90[kw]   Qerr = 7.58%
Meas. V =16.325 [volts]   Calc. V =16.139 [volts]   Verr = 1.140%
Meas. I =2445.6 [amps]   Calc. I =2473.8 [amps]   Ierr = 1.15%
Meas. Tout = 11.4 [F]   Calc. Tout = 22.8 [F]   Terr = 11.4 [F]